HP 16C EMULATOR
HP-41 Module

User's Manual and QRG.

Written and Programmed by Greg J. McClure and Ángel M. Martin

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Screen captures taken from V41, Windows-based emulator developed by Warren Furlow.
See www.hp41.org

Acknowledgments.-

Special thanks go to Greg McClure for his tremendous work on the 16C Emulator module – his 16C Buffer design and handling routines, together with the "big math" algorithms are the heart and soul of this module.

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Thanks to Michael Fehlhammer for making the 16C overlay a reality in such a short time even before the module release.

HP 16C Emulator Module

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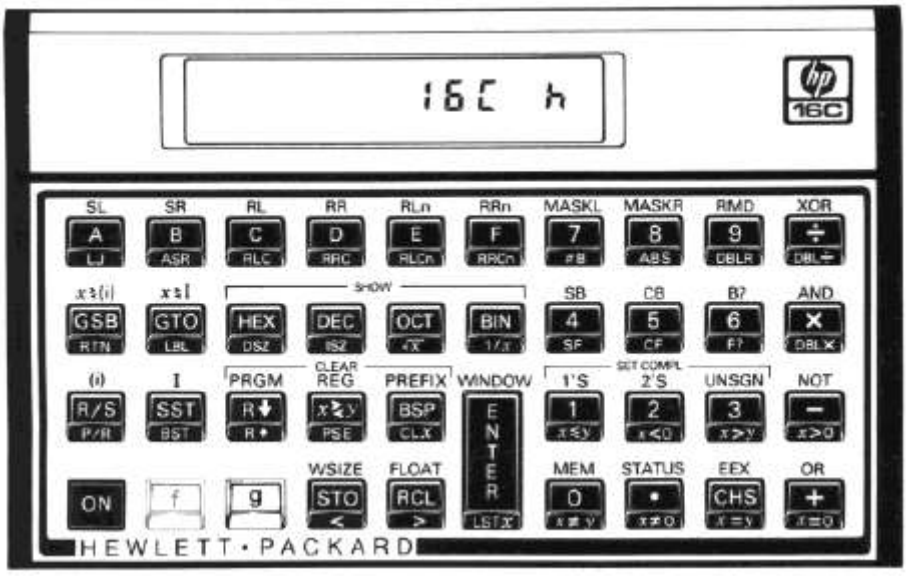


HP 16C Emulator Module

Computer Science for the HP-41CX

1. Introduction.

At long last, a complete solution for the Computer Scientist on the HP-41 platform is finally available in the form of the HP-16C Emulator module.

This module provides a comprehensive feature set that includes all the functionality from the original HP-16C, plus a few new surprises and extensions added to the design. Support for up to 64-bit word size is provided in all functions – beyond any previous attempt implemented on the 41 system ever before.

The design takes full advantage of the alphanumeric capabilities of the 41, in particular the 24-character LCD for more convenient number entry and display. Prompting functions and X-Memory backup enhance the usability and go beyond the original machine. Use them in manual operation or in a program, all functions are completely programmable.

Auxiliary FAT, Bank-switching and Page#4 Library.

The 16C Emulator module comes loaded with functions and a rich feature set – yet it only takes a single page (i.e. half port) on the 41 ROM module bus. Its structure consists of four bank-switched 4k blocks, with functions arranged in two Function Address tables – the main one filled-up with 64 functions plus an auxiliary one containing additional sub-functions. All are programmable, and easily accessed using dedicated function launchers. Plus a complete 16C Keyboard overlay is available for instant plug-and play functionality.

The 16C Emulator is a Library#4-aware module: it makes extensive usage of the library routines for more efficient execution as well as management of the auxiliary FAT and sub-function launchers - which relies on the presence of the Library#4 installed on the system. The Library#4 has been updated for the 16C Emulator, thus *ensure you have revision "O1",* with MOD file date August 2015.

The last remark is regarding the CX dependency: designed for the CX version of the 41 OS, the code occasionally uses subroutines from the CX OS code. This was a compromise to enhance the functionality at the economy of ROM space – as it avoided having to replicate large code streams already available on the CX. Don't use this module on a plain 41C or CV machine, it'll have surely unexpected and probably unwanted results.

The module checks for the presence of the dependencies, i.e. the Library#4 and the CX.-- If the Library#4 is missing or the machine is not a CX the errors will halt it to avoid likely problems. Note also that this module is not compatible with pages#6 and 7 – avoid plugging it in those locations.

Remember: The HP16C Emulator module extensively uses routines and functions from the Page#4 Library. Make sure the Library#4 revision "O1" (or higher) is installed on your system or things can go south. Refer to the Page#4 Library documentation to properly configure the Library#4 before use.

Organization of this manual.

We have no intention to duplicate the HP-16C Computer Scientist Manual – which is the best reference to learn about the functions and concepts behind this module. This manual won't teach you the intricacies of the Carry and Out of Range flags, or the binary concepts behind the 1's or 2's complement signed modes for instance. You're encouraged to read the original 16C manual if needed.

It is however important to document the main design criteria applied to the 16C Emulator module and the derived consequences for its use. Special attention has been put to the new and additional functions, as well as documenting the small differences that may exist in a few functions when compared to their original implementation on the 16C calculator.

It is expected that the reader be already familiar with the HP-41 environment, so as to be comfortable keying instructions and operating the machine. A basic knowledge of the 41 system memory structure and programming will be very useful if you also want to use the 16C module functions in your own programs.

This module employs several powerful concepts also present in other advanced modules, such us a secondary FAT to hold auxiliary sub-functions; several function launchers that group functions and sub-functions by related functionality; and the LAST Function facility to re-execute the last function (or sub-function) called - to mention just the most important ones. You may be familiar with all these had you already used the SandMath, SandMatrix or PowerCL modules. You don't need a 41-CL to run this module but obviously its tremendous speed advantage makes it the best possible choice of hardware.

Some remarks about the implementation.

Emulating the complete capabilities of the original 16C machine has been a tall order, only possible thanks to a fortuitous combination of dedication and skills from both co-authors. Greg's programming skills have been put to a good use in the base conversion and "big math" algorithms - which work seamlessly integrated into the module completely behind the scenes.

The double precision multiplication and division in particular are highlights of the module, taking up the third bank in its entirety by themselves – which speaks volumes about their intricate design and complex implementation.

From my part this module brings it all together home in many ways; starting with the advanced concepts borrowed from the 41Z Complex module (dealing with auxiliary buffers for data storage and abstraction data layers above the native real numbers support on the 41 OS); from the SandMath and PowerCL modules (pioneering the function Launchers) and of course the heavy reuse of Auxiliary FATS and sub-function management leveraging the Library#4 design way beyond its initial design scope.

All in all, this module is nothing short of an improbable amazing feat if you ask me, and I think I speak on both Greg's and my own behalf to say it's an important contribution to the 41 legacy. It has been a very rewarding project, and a great learning opportunity for me as well – thank goodness Greg was on watch to keep all those whimsical components of the 16C intricacies at bay many times during the development, when I was getting completely confused!

PS. The trademark "*Martin-McClure*" is a result of a virtual coin toss and some consideration as to the "ringing" of the words – but under no circumstance denotes any priority in the order of the names.

Function index at a glance.-

Without further ado, here are all 125 functions included in the main and auxiliary FATs.

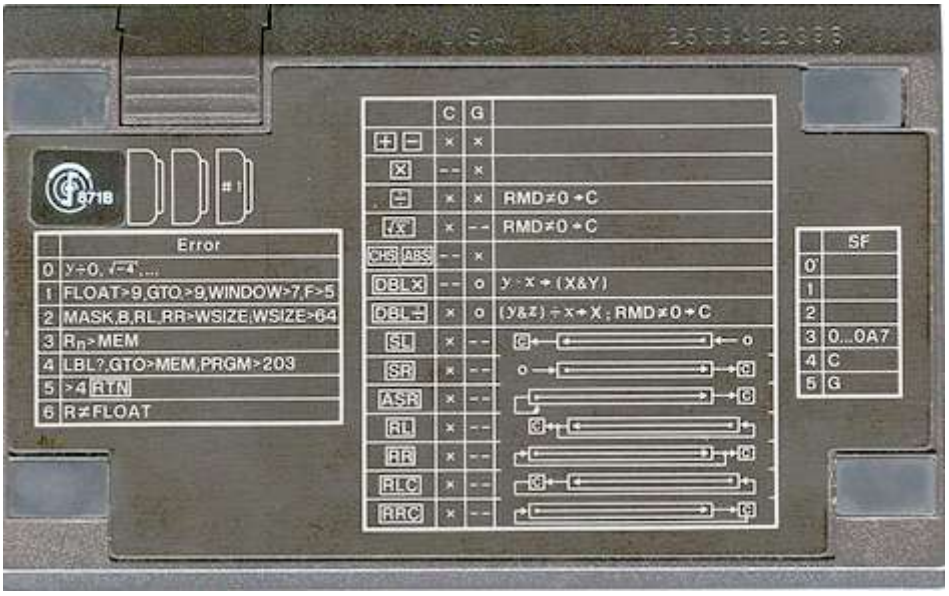
#	Function	Description	Input	Result
1	-HP-16C+	Shows Library#4 Splash	none	Flashes splash msg
2	**16C _**	Main 16C Keyboard Launcher	see 16C keyboard overlay	executes function
3	**16# _ _ _**	WEX Subfunction by index	Prompts for index	executes function
4	**16$ _**	XEQ sub-function by Name	Prompts for name	executes function
5	**16+**	Integer mode addition	values in 16X and 16Y	Result in 16X, stack drops
6	**16-**	Integer mode subtraction	values in 16X and 16Y	Result in 16X, stack drops
7	**16***	Integer mode multiplication	values in 16X and 16Y	Result in 16X, stack drops
8	**16/**	Integer mode Division	values in 16X and 16Y	Result in 16X, stack drops
9	**16SQRT**	Square Root	value in 16X	result in 16X, argument to 16L
10	**16WSZ _ _**	Sets Word Size	prompts for word size	flashes size on LCD
11	**1CMP**	Sets 1's Complement Mode	none	changes mode, sets flag 1
12	**2CMP**	Sets 2's Complement mode	none	changes mode, sets flag 2
13	**AND**	Logical Intersection	values in 16X and 16Y	Result in 16X, stack drops
14	**ASR**	Arihtmetic Shift Right	value in 16X	result in 16X, argument to 16L
15	**b? _ _**	Bit Set testing	value in 16X, bit# in prompt	YES/NO, skips line if false
16	**BINM**	Binary Base display	none	changes displayed base
17	**Cb _ _**	Clears bit	value in 16X, bit# in prompt	result in 16X, argument to 16L
18	**DBL***	Double precision 16*	values in 16X and 16Y	Result in 16X & 16Y, stack drops
19	**DBL/**	Double Precision 16/	values in 16X, 16Y, 16Z	pushes value into 16C stack
20	**DBLR**	Double Prec. Remainder	values in 16X, 16Y, 16Z	pushes value into 16C stack
21	**DECM**	Decimal base display	none	changes displayed base
22	**FLOAT**	Floating Point mode	none	supresses displaying mode!
23	**HEXM**	Hexadecimal Base display	none	changes displayed base
24	**LJY**	Left Justify	value in 16X	Result in 16X, #pos in 16Y
25	**MASKL _ _**	Builds a Left-justified Mask	# of bits in prompt	pushes value into 16C stack
26	**MASKR _ _**	Builds a Right-justified Mask	# of bits in prompt	pushes value into 16C stack
27	**NOT**	Logical Inversion	value in 16X	result in 16X, argument to 16L
28	**OCTM**	Octal Base display	none	changes displayed base
29	**OR**	Logical Addition	values in 16X and 16Y	Result in 16X, stack drops
30	**RL**	Rotate Left (one pos.)	value in 16X	result in 16X, argument to 16L
31	**RLC**	Rotate Left thru Carry	value in 16X	result in 16X, argument to 16L
32	**RLCN _ _**	RLC n-positions	value in 16X and prompt	result in 16X, argument to 16L
33	**RLN _ _**	Rotate Left n-positions	value in 16X and prompt	result in 16X, argument to 16L
34	**RMD**	Division Remainder	values in 16X and 16Y	pushes value into 16C stack
35	**RR**	Rotate Right (one pos.)	value in 16X	result in 16X, argument to 16L
36	**RRC**	Rotate Right thru Carry	value in 16X	result in 16X, argument to 16L
37	**RRCN _ _**	RRC n-positions	value in 16X and prompt	result in 16X, argument to 16L
38	**RRN _ _**	Rotate Right n-positions	value in 16X and prompt	result in 16X, argument to 16L
39	**Sb _ _**	Set bit	value in 16X, bit# in prompt	result in 16X, argument to 16L
40	**SHOW**	Shows value in 16X	value in 16X	Puts value chars in ALPHA
41	**SLN _ _**	Shift Left n-positions	value in 16X and prompt	result in 16X, argument to 16L
42	**SRN _ _**	Shift Right n-positions	value in 16X and prompt	result in 16X, argument to 16L
43	**STATUS**	Shows Status Info	base and complement data	Shows machine status msg
44	**UCMP**	Sets Unsigned mode	none	changes mode, sets flag 0
45	**WINDOW _**	Shows the Window registers	values in FX buffer regs	shows FX registers on LCD
46	**XOR**	Exclusive OR	values in 16X and 16Y	Result in 16X, stack drops
47	**ΣLEFT _**	Left Launcher	prompts for function	executes function
48	**ΣMOD _**	Modes Launcher	prompts for function	executes function
49	**ΣROT _**	Rotations Launcher	prompts for function	executes function

50	-16C STACK	Shows Copyright & Sound	n/a	Flashes message & sounds
51	**16ABS**	Absolute value	value in 16X	result in 16X, argument to 16L
52	**16CHS**	Changes 16X sign	value in 16X and compl mode	result in 16X, argument to 16L
53	**16ENT^**	Pushes 16X one level up	values in 16C stack	16X in entered to 16Y
54	**16NPT**	Main Data Input function	Characters in ALPHA	next value entered in 16X
55	**16RCL _ _**	Recalls value from memory	values in data registers	value from memory into 16X
56	**16RDN**	Rolls the 16C stack down	values in 16C stack	16C stack rolled down
57	**16RUP**	Rolls the 16C stack Up	values in 16C stack	16C stack rolled up
58	**16STO _ _**	Stores 16X in memory	value in 16X and prompt	16X stored in data registers
59	**16X<> _ _**	Exchanges the 16X and mem	values in 16X and data regs	16X and data regs exchanges
60	**16X<>Y**	Swaps 16X and 16Y	values in 16X and 16Y	16X and 16Y exchanged
61	**CL16X**	Clears the 16X register	anything in 16X	16X is zeroed
62	**CL16ST**	Clears al the 16C stack	anything in 16C stack	the 16C stack is zeroed
63	**LST16X**	Recalls last value used	value in 16L reg	pushes 16L into 16X
64	**X?Y _**	XY Tests launcher	XY tests launcher	executes function
0	-16C FAT2	Section header	section header	n/a
1	**ΣBIT _**	Bit Functions Launcher	prompts for function	executes function
2	**ΣSHF _**	Shift/Bist Launcher	prompts for function	executes function
3	**ΣRIGHT _**	Right Launcher	prompts for function	executes function
4	**16APN**	Append String to Value	Partial String in Alpha	Appends to Exisiting Value
5	**16x^2**	Squares 16X	value in 16X	result in 16X, argument to 16L
6	**16X=0?**	tests 16X equal to zero	value in 16X	YES/NO, skips line if false
7	**16X#0?**	tests 16X not equal to zero	value in 16X	YES/NO, skips line if false
8	**16X<0?**	tests 16X less than zero	value in 16X	YES/NO, skips line if false
9	**16X<=0?**	tests 16X less or equal to 0	value in 16X	YES/NO, skips line if false
10	**16X>0?**	tests 16X greater than zero	value in 16X	YES/NO, skips line if false
11	**16X>=0?**	tests 16X greater or equal 0	value in 16X	YES/NO, skips line if false
12	**16X=Y?**	tests 16X equal to 16T	values in 16X and 16Y	YES/NO, skips line if false
13	**16X#Y?**	tests 16X not equal to 16Y	values in 16X and 16Y	YES/NO, skips line if false
14	**16X<Y?**	tests 16X less than 16Y	values in 16X and 16Y	YES/NO, skips line if false
15	**16X<=Y?**	tests 16X less/equal to 16Y	values in 16X and 16Y	YES/NO, skips line if false
16	**16X>Y?**	tests 16X greater than 16Y	values in 16X and 16Y	YES/NO, skips line if false
17	**16X>=Y?**	tests 16X great/equal to 16Y	values in 16X and 16Y	YES/NO, skips line if false
18	**16X^^^**	enters 16X in all stack levels	value in 16X	16X is replicated
19	**DSZ**	Decrement and skip if Zero	content of R00 data reg	R00 decrements, skip iz aero
20	**GET16**	Gets 16C buffer from X-Mem	X-mem file name in ALPHA	new 16C buffer is in place
21	**ISZ**	Increment and skip if zero	content of R00 data reg	R00 increments, skip iz aero
22	**LOW16^**	Enters x into 16X register	real number value in x	new value in 16X
23	**NAND**	Negative AND	values in 16X and 16Y	Result in 16X, stack drops
24	**NOR**	Negative OR	values in 16X and 16Y	Result in 16X, stack drops
25	**REV**	Reverses bits in word	value in 16X	result in 16X, argument to 16L
26	**RJY**	Right Justifies the value	value in 16X	Result in 16X, #pos in 16Y
27	**SAVE16**	Saves 16C buffer in X-Mem	X-mem file name in ALPHA	buffer saved in X-Mem file
28	**SL**	Original Shift Left function	value in 16X	result in 16X, argument to 16L
29	**SR**	Original Shift Right function	value in 16X	result in 16X, argument to 16L
30	**WSFIT**	Fits the word size to 16X value	value in 16X	ws changed
31	**X?0 _**	Tests to zero Launcher	X0 tests launcher	executes function
32	**XNOR**	Negative XOR	values in 16X and 16Y	Result in 16X, stack drops
33	**#BITS**	Gets sum of selected bits	value in 16X	Returns sum of bits to 16X
34	**FCAT _**	Sub-function Catalog	has hot-keys	enumerates sub-functions
35	-TESTING	Section header	section header	n/a
36	**16KEYS**	Mass-Key Assignments (*)	Prompts Y/N?	Makes / Removes KA
37	**16WSZ?**	Retrieves current word size set	ws data from buffer	Shows ws and puts it in 16X
38	**2DIV**	Halves the content of 16X	value in 16X	result in 16X, argument to 16L

39	**2MLT**	Doubles the content of 16X	value in 16X	result in 16X, argument to 16L
40	**A2FX**	Alpha to FX registers	String in ALPHA	Chars transferred to FX regs
41	**BASE?**	Recalls base to 16X	none	Base value in 16X
42	**CHKBB**	Checks & Builds the 16C buffer	none	16C Buffer in Memory
43	**CLRFX**	Clears FX buffer registers	none	FX regs cleared (reset)
44	**D>H**	Decimal to Hex	Value in X-reg	Hex string in Alpha
45	**DGDΣ**	Decimal Digit Sum	Value in 16X	Shows sum and enters it
46	**DGLJ**	Digit Left-justify	Value in X-reg	Digits left-Justified
47	**DGRV**	Digit Reversal	Value in 16X	Reversed digits in 16X
48	**EX2FX**	Copies the EX regs to the FX regs	Binary Data in EX regs	Chars written in FX Regs
49	**FX2EX**	Copies the FX regs to the EX regs	Chars Data in FX regs	Binary Data in EX regs
50	**FXSZ?**	Shows number of non-zero chrs in FX	none	Number of characters in X
51	**H>D**	Hex to Decimal	Hex String in Alpha	Result in X-register
52	**H=L**	Copies the Low bits into the High bits	Data in 16X	Copies X to b13
53	**L-H**	Moves the Low bits to the High bits	Data in 16X	Moved X to b13
54	**L<>H**	Swaps Low and High 16X bits	Data in 16X	X-reg and b13 swapped
55	**LDZER**	Shows Leading Zeros	Data in 16X	Leading Zeros added
56	**MNV?**	Test for Maximum Negative Value	Value in 16X	YES/NO, skips line if false
57	**TS/L**	Toggles Silent/Loud Mode	none	Active mode toggled
58	**WSMAX**	Shows maximum value for ws	ws data in buffer	shows value in x
59	**X-LA**	Appends chr(X) to laft-Alpha	Crh value in X	Appended to left Alpha
60	**(c)**	Shows Copyright Message	none	Shows message

If you're familiar with the 16C calculator you'll no doubt recognize the majority of functions in the main FAT – as such as been the criteria for function FAT allocation. Their functionality and operation should be pretty much identical to their original counterparts, but there are a few differences that will be covered later in the manual.

Hopefully you're also intrigued about the new additions to the function set (located in the auxiliary FAT), and can probably guess their scope and intention – that will be the subject of dedicated sections as well, as they are likely to add some surprises to the digital mix. Refer to the table in next page for a quick comparison between new, modified and original functions in the emulator.



Always ensure that Revision "01" or higher of the Library#4 is installed on the system.

Original Functions		Modified Functions		New Functions	
1	#BITS	1	-16C FAT2	1	ΣBIT _
2	16-	2	-16C STCK	2	ΣLEFT _
3	16*	3	-HP 16C+	3	ΣMOD _
4	16/	4	-TESTING	4	ΣRIGHT _
5	16+	5	16APN	5	ΣROT _
6	16ABS	6	16NPT _	6	ΣSHF _
7	16CHS	7	16RCL _ _	7	16# _ _ _
8	16ENT^	8	16STO _ _	8	16$ _
9	16RDN	9	16WSZ _ _	9	16C _
10	16RUP	10	b? _ _	10	16KEYS _
11	16SQRT	11	Cb _ _	11	16WSZ?
12	16X#0?	12	LJY	12	16X^^^
13	16X#Y?	13	LDZER	13	16X^2
14	16X<=0?	14	LOW16^	14	16X<> _ _
15	16X<=Y?	15	MASKL _ _	15	16X>=0?
16	16X<>Y	16	MASKR _ _	16	16X>=Y?
17	16X<0?	17	RLCN _ _	17	2DIV
18	16X<Y?	18	RLN _ _	18	2MLT
19	16X=0?	19	RRCN _ _	19	A2FX
20	16X=Y?	20	RRN _ _	20	BASE?
21	16X>0?	21	Sb _ _	21	CHKBB
22	16X>Y?	22	WINDOW _	22	CL16ST
23	1CMP			23	CLRFX
24	2CMP			24	D>H
25	AND			25	DGDΣ
26	ASR			26	DGLJ
27	BINM			27	DGRV
28	CL16X			28	EX2FX
29	DBL*			29	FCAT _
30	DBL/			30	FX2EX
31	DBLR			31	FXSZ?
32	DECM			32	GET16
33	DSZ			33	H=L
34	FLOAT			34	H>D
35	HEXM			35	L<>H
36	ISZ			36	L-H
37	LST16X			37	MNV?
38	NOT			38	NAND
39	OCTM			39	NOR
40	OR			40	REV
41	RL			41	RJY
42	RLC			42	SAVE16
43	RMD			43	SLN _ _
44	RR			44	SRN _ _
45	RRC			45	TS/L
46	SHOW			46	WSFIT
47	SL			47	WSMAX
48	SR			48	X?0 _
49	STATUS			49	X?Y _
50	UCMP			50	X-LA
51	XOR			51	XNOR
				52	(c)

2.- 16C DATA STRUCTURE

2.1. The *Martin-McClure* Buffer

Without doubt the 16C-Buffer is the cornerstone of the 16C Emulator module. Designed to fulfill the storage requirements for 64-bit data values and provide available scratch registers for data management and auxiliary calculations, this buffer is automatically created and maintained by the calculator behind the scenes - all transparent to the user.

Even if you can use the module completely unaware of the 16C buffer, knowing the fundamentals on its structure and operation will largely increase you understanding of the module - significantly smoothing the learning curve. Those wanting to know more should refer to appendix B for a more detailed description of the buffer registers and design.

Data Size and Registers: the problem at hand.

Because the data values can be as large as 64-bit, the 56-bit standard 41C registers are not sufficient to hold the values in all cases- even if we were to use up all of them in a custom data format.

The solution implemented uses two standard hp-41 registers for each 16C value, with each register holding 32-bits worth of information. We'll call those registers the "lower bits" and the "higher bits" registers. This is so regardless of the selected word size, thus the higher bits register will be empty when the value can be expressed by 32- or less number of bits.

The 16C Stack is the first abstraction layer you need to become familiar with. Like its "standard" counterpart {X,Y,Z,T,L}, the 16C Stack consists of 5 logical 64-bit registers, named 16X, 16Y, 16Z, 16T, and 16L (or Last16X). Physically each one of these is made as the logical combination of the standard stack register of the same name plus another register from the 16C Data Buffer. As you'd expect, the standard stack contains the "lower bits" half of the value, whilst the buffer register holds the "higher bits".

Register	Lower Bits	+	Upper Bits
16X	X		b13
16Y	Y		b12
16Z	Z		b11
16T	T		b10
16L	L		b14

2.1.1 16C Stack Operation functions.

A set of functions is provided to operate on the 16C registers as whole unit – including both the lower and upper bits halves simultaneously. It is important that you remember that the standard functions of the calculator will only access the lower bits halves, and thus you should use the 16C functions instead – unless you're already on the grand-master level and begin hacking around.

These functions include the 16C stack handling (usual suspects here: **16ENT^**, **16X<>Y**, **16RDN**, **16RUP**, **CL16X**, **CL16ST**) as well as exchange with the other data registers in the calculator memory: **16STO**, **16RCL**, and **16X<>**. The last three are also programmable using the "non-merged" approach – whereby the target register number is entered as a follow-up line in the program.

2.1.2. Stack and Memory Functions.

The table below summarizes all functions and sub functions related to stack and memory handling.

Function	Description	Comment
16ENT^	Pushes 16X into the 16C stack	Lifts 16C Stack
LOW16^	Pushes x into 16X level	Lifts 16C stack
16X<>Y	Swaps 16X and 16Y levels	
16RDN	Rolls down the 16C stack	
16RUP	Rolls up the 16C stack	
16X^^^	Copies 16X into all 16C levels	
LST16X	Recalls the last value to 16X	Lifts 16C stack
CL16X	Clears the 16X level	
CL16ST	Clears all 16C stack	
16STO _ _	Stores 16X in memory	Uses two data regs
16RCL _ _	Recalls value from memory	Lifts 16C Stack
16X<> _ _	Exchanges 16X and memory	Uses two data regs
SAVE16	Writes 16C stack to X-Mem	Creates "H"-type file
GET16	Reads 16C stack from X-mem	Only one buf allowed

Data registers Usage and Required SIZE

Max 16RG#	Size
n/a	1
16R00	2 3
16R01	4 5
16R02	6 7
16R03	8 9
16R04	10 11
16R05	12 13
16R06	14 15
16R07	16 17
16R08	18 19
16R09	20 21
16R10	22 23
16R11	24 25
...	...

Note that **16STO**, **16RCL** and **16X<>** are prompting functions. As explained before, two data registers are used to store the 16X values in memory. Refer to the table on the left for a correspondence between the register# used in the prompt and the actual SIZE required in the calculator to allow for the range of 16C data registers needed.

Note that R00 is used by the **ISZ** and **DSZ** sub-functions as the "indirect" register – therefore and to avoid conflicts the actual registers usage in the 16C registers scheme begins with {R01 & R02} for the 16C- version of "16R00". This makes them compatible with each other so you don't have to worry about it.

Remember that you can also use the 41-native functions ISG and DSE instead for a more powerful implementation that allows you to choose the indirect register used. In that case you need to mind the potential register conflicts!

Now that we've got the data requirements and design considerations out of the way let's see how to go about introducing and reviewing actual 16C values in the calculator.

2.2. Data Input. - { 16NPT , LOW16^ , 16APN }

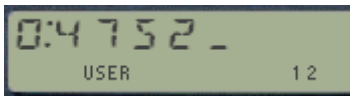
If the 16C buffer is the invisible heart of the module then the **16NPT** function is its visible counterpart. This is the function you'll be using most of the time to enter the data values and arguments for your calculations – regardless of the selected base and complement mode set.

When invoked, the function prompts for the digit values to input, showing the selected base on the left side of the display. The data is input as alphanumerical digits on the LCD display during the process. Only the appropriate digits for each base will be allowed.

You can enter up to 24 digits at a single time, or split the entry in three different sub-sections (called "partials") if so preferred. Obviously for large values in Binary mode this last method will become necessary, but for all other bases a single partial is enough to hold the maximum numbers allowed even for a 64-bit word size.

The digit entry can be completed only partially by pressing the SST key – this will commit the digits to the 16C buffer and will present the base prompt anew, ready for the next partial entry. The second partial is then appended to the first one, and this can be repeated again for the third (and last) partial – so even a 64-bit value in binary can be entered using three segments of data.

The flag annunciators are temporarily "borrowed" by **16NPT** to show you which partial you're working on at any time. Thus you'll see "1", "12", or "123" depending on which one of the three partial screens you're in at any given time. Once completed, their status will revert back to their previous values prior to executing 16NPT.



Note that the back-arrow key will either delete the current digit, or cancel the function if there are no more digits left on the display. This will show the value in 16X previous to the execution of 16NPT, or *enter the current partials already committed to* if a partial entry had already happened.

Note as well that only 12 characters are displayed on the LCD at a given time. If you enter more the previous will be scrolled to the left and removed from view (but not lost, not to worry about that). The back arrow removes the rightmost digit but won't scroll the string back to the right.

The digit entry is terminated pressing ENTER^ or R/S indistinctly, upon which the information is shown as alphanumeric string in ALPHA (scrolling if larger than 12) and transferred to the 16CX register. The 16C Stack is lifted as you'd come to expect, same as with the standard stack. At that point you're done and ready to move on to the next action.

There are several usability features built into the 16NPT function that make it easy to use and as closer to the original 16C as reasonably possible – balancing the code requirements and the general performance considerations. They are described in the following paragraphs.

Maximum values will be observed.

Not only does **16NPT** know which digits are allowed for the current base, but it also *limits the entry values according to the currently selected word size and complement mode* – so the maximum value is not exceeded. This however has an exception in *decimal mode for word sizes of **34** and up*, where in some circumstances values slightly larger than the maximum can be keyed in. They however will be *normalized* upon data entry completion, by applying the current mask to the digits in ALPHA.

Examples: in DEC mode and 2CMP, select word size = 34 and attempt to enter the following two values: 8,589,934,595 and 8,589,934,999. Are the results what you had expected?

16NPT, 8, 5, 8, 9, 9, 3, 4, 5, 9, 5, ENTER^ => d: -8,589,934,589
16NPT, 8, 5, 8, 9, 9, 3, 4, 9, 9, 9, ENTER^ => d: -8,589,934,185

Direct Math and Negative Values entry. { 16NPT, CHS , - , + , * , / }

A special way to terminate the digit entry is by pressing one of the four arithmetic keys for a direct (chained) operation; or the CHS key to directly enter the negative value of the number typed in. This not only saves three keystrokes but also provides a convenient way to introduce negative numbers not worrying about the current complement mode.

Example: enter the negative value of H: 25, with a word size of 32 and 2's complement:
16NPT, 2, 5, CHS => H: FFFFFFDB

On-the-fly Base Rotation during Input. { 16NPT, [SHIFT] }

Another usability feature of **16NPT** allows you to change the selected base mode on the fly, directly from the 16NPT prompt. Pressing the [SHIFT] key will toggle the selected base amongst the four possible ones, in the sequence {HEX -> OCT -> DEC -> BIN}, repeated cyclically.

Note that each time you change the base the contents of ALPHA and FX registers will be reset, including the existing "partials" if previously entered - so you'll start the digit entry process from the scratch. This ensures that only appropriate characters for the new base are in the FX buffer, rejecting previously entered ones before the base change.

If you cancel the data entry the current value in the 16X register will be shown again - in the last base mode selected during the cyclic rotation.

Quick-Entry Shortcut for lower-bit values. { 16NPT, [RADIX] }

Besides the normal procedure explained before, there is a quick-entry mode also available *for values below the 32-bit limit*, i.e. only impacting the "lower bits" half of the 16X register.

Simply type the (floating point) BCD value using the standard X-register, then call **16NPT** and hit the radix key (decimal point). This will call the **LOW16^** function, effectively terminating the entry appending the number in X as data input, clearing the higher bits and lifting the 16C stack appropriately.

The entered value will be shown in the currently selected base mode, thus it'll only be equal to the BCD input in decimal mode. For example the sequence 12345, **LOW16^** will return H: 3039

Program Mode Operation { 16APN }

You're no doubt wondering how the data is input under program control, where all the hot keys and shortcuts are not available. The first thing to say is that **16NPT** is indeed programmable, and that in a running program it takes its input (digits) from the ALPHA register.

Therefore this is already good enough to enter any values in Octal, Decimal and Hexadecimal modes regardless of the word size selected. For binary mode you may need to **append** more data after the first 24 digits are dealt with this way if the word size is larger than 24 bits – as in binary each bit is a full ASCII digit. You'll then use the **16APN** sub-function for that purpose, effectively performing the same trick as with the [SST] key in manual mode to enter partials.

As an example let's see two possible ways to input the hexadecimal value "1234ABCD", illustrating the usage of **16NPT** and **16APN** choices at your disposal.

#1 Choice: only two program lines required,

```
01  "1234ABCD"
02  16NPT
```

#2 Choice: it takes four lines to do the same:

```
01  "1234"    first part (break at will)
02  16NPT
03  "ABCD"    second part
04  16APN
```

Note that because **16APN** is a sub-function, the last line in the second choice is really two program lines, as you need function **16#** and the corresponding index. Refer to the sub-function launchers section for further details on **16#** and **16$**).

As a last remark, it comes without saying that the characters in ALPHA should conform to the selected base and word size restrictions. There won't be any error message if this is not done, but as a rule the function will always normalize the input, applying the current mask against it in program mode – thus possibly changing the input (but wrong) entry into allowed values.

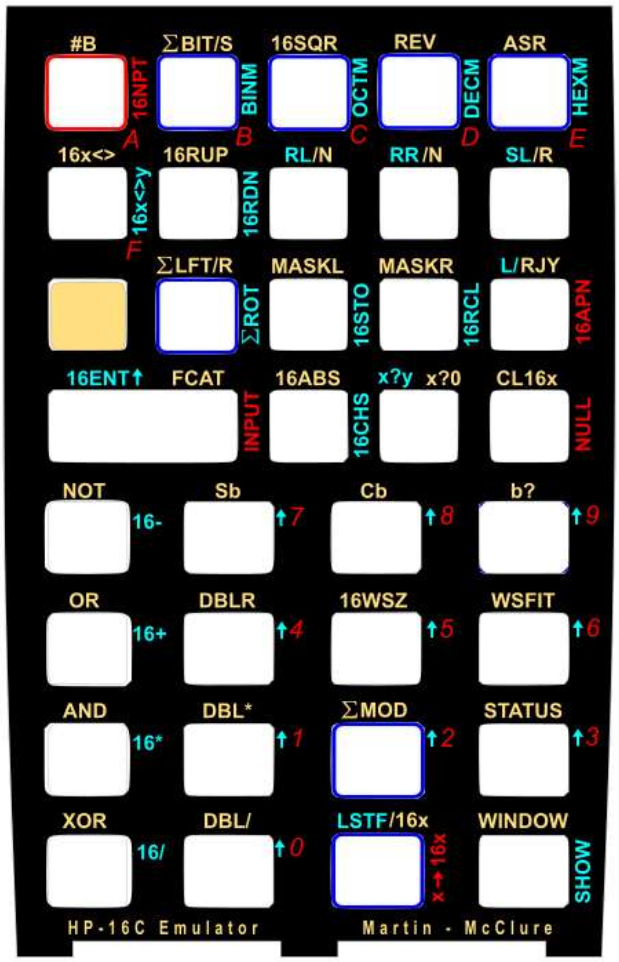
Summary of 16NPT hot-keys:

- ENTER^ terminates the digit entry.
- R/S terminates the digit entry
- SST appends digits to buffer and moves to next partial
- CHS terminates digit entry and changes the sign
- [-] terminates digit entry and does subtraction
- [+] terminates digit entry and does addition
- [*] terminates digit entry and multiplies by 16Y value
- [/] terminates digit entry and divides by 16Y value
- [SHIFT] discards digits and changes base mode on the fly
- [RADIX] discards digits and enters low-bits value from X register
- [BackArrow] deletes last digit or cancels out if last one.
- [ALPHA] launches the **16$** function

Note: characters "b" and "d" are shown in lower case for clarity – even if the 41 LCD is better than the original on the 16C this implementation gives the emulator a feeling closer to the real machine.

The 16C Digit Pad and 16C Keyboard Overlay.

Related to the quick entry modes, you can also use the **16C** digit-pad to directly enter 1-9 single digits as values. This is done *from the 16C prompt, no need to call 16NPT at all* – so even if its applicability is limited to single-digit integers it doesn't get any easier. Some typical uses for this functionality include quick arithmetic (double, half, triple, etc.) and integer values used as parameters for other functions. The picture below shows the 16C Keyboard Overlay in all its glory, where the options for **16NPT, LOW16^** and the digit pad are shown in red color.



All functions shown on this overlay require pressing the **16C** main launcher first.

Note: You can assign the 16C function to any location on the keyboard. Because it is used very frequently it's recommended you change that location from time to time to avoid the associated hardware wear & tear on the key domes.

Always ensure that Revision "01" or higher of the Library#4 is installed on the system.

2.3. Data Output – { SHOW, WINDOW }

When executed in manual mode (RUN), every function in the 16C Emulator module terminates the execution by calling the data output routines - also directly available in function **SHOW**. This presents the result value as a (possibly scrolling) string of digits in the ALPHA registers, preceded by the base indicator on the left. For a more effective presentation **SHOW** will leave out the padding zero characters to the left of the first significat digit, regardless of the selected word size.

This includes the 16C stack and memory handling function like **16X<>Y** or **16RCL**; so the user can always expect to see a proper integer "digital" value as result of the operation.

This presentation will be omitted when the functions are executed in a program, with the exception of **SHOW** itself which will put the result in ALPHA and stop the program if the user flag 21 is set - as it is the case for the native function AVIEW.

Another possible option to visualize the value in the 16X register is the function **WINDOW**. Like in the original 16C, it presents the value across a variable number of 8-character windows, as many as needed to cover the actual length of the value. For instance in binary base with a word size of 56 it may take up to 7 windows to review the complete result (maybe less since here too padding zeros on the left won't be shown).

Contrary to the original 16C however the listing starts with the MSB in window 0 (the first one), and this will always be shown when you call the function. The succesive characters will be placed in the following windows – until the LSB is placed in window 6 for the example mentioned above.

The user can navigate sequentially through the windows pressing the [+] and [-] keys, or randomly get into any specific window by presing its corresponding number (from 0 to 7) on the number pad. You'll then use the back arrow key to leave the show, so to speak.

The windows are numbered from "W0:" to "W7:" placed at the left of the LCD. The selected base character is also shown the the right of the LCD in all cases .

When used in a program, **WINDOW** will take the argument# from the next program line as a non-merged design – similar to other prompting functions like 16STO and 16RCL.

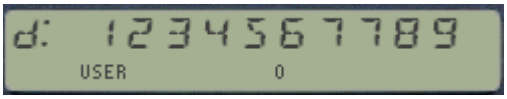
The True Meaning of GRAD revealed.

If you always thought that it stood for a so-called centesimal angular mode seldom-used (except by surveyors we're told) then you're in for a nice revelation ;-)

GRAD really stands for "**GR**eater than **A**lpha **D**isplay" - The GRAD annunciator will be lit when the value to display exceeds the 24-character limit of the ALPHA registers, as a visual clue that you need to use **WINDOW** to see the complete value.

This will only occur in binary base mode, with word sizes larger than 24 bits, and when the significant bits exceed that number (remember the leading zeroes won't be shown). Every other case is well-served by **SHOW** using the ALPHA register - even if it is exercising its scrolling capacity.

Let's see an example using a large word size (say ws=56). Enter the decimal value 1234567789, and show it in binary using the WINDOW function screens:



Exceute **BINM** (this sets GRAD), and **WINDOW**. Then use the hot keys to access all the relevant screens as follows: - Note the storage order of the bits, with the MSB in the leftmost position of W0 and the LSB at the rightmost position of W3

Therefore the binary bit stream is as follows:

B: 1 001 001 100 101 100 000 001 001 101 101

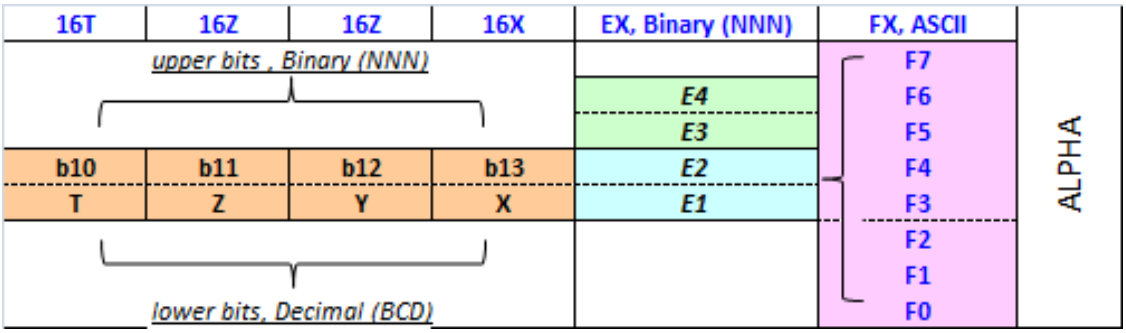
Summary of Data formats used throughout the registers.

Data is stored in different formats depending on the registers they are in.

- The lower bits registers in the standard stack are stored in BCD (Binary-Coded Decimal) format, thus you can see them like regular decimal values if you exit the displayed prompt from the 16NPT output (say for instance pressing the back arrow).

- The higher bits registers in the 16C buffer are stored in binary format, i.e. Non-normalized numbers or NNN's. Realize that for any math operation the lower-bits first will be converted to binary, and only then the operation will be applied.

- The visual representation in the "Window" buffer registers is stored as character digits in ASCII code. It may take up to 64 characters; therefore there are 8 "Window" registers like in the original 16C machine. Realize that whilst the ALPHA register is the repository for **SHOW**, the information shown in the **WINDOW** screens uses the LCD as a vehicle instead.



3.- WHAT'S NEW & DIFFERENT

3. 1.- Differences from the original 16C.

The obvious differences are the dedicated hardware - like the keyboard layout and the LCD. These account for the most dramatic changes in utilization, since on the 41 the 16C Emulator is just one of the many other modules that can be used simultaneously, and it needs to co-exist with the 41 native OS.

But far from being a disadvantage that makes it much more interesting, as you benefit from the power and capability offered on the 41 like extendend capacity in data registers and program space, larger LCD with automatic scrolling functionality, and of course the ability to compbine the 16C functions with any other from the 41 OS at the same time.

Is it a better 16C than the original 16C? Well that depends on your previous experience and bias – so if you live and breathe by the original machine this module will make you do things a little different – but if you're just a casual user or start anew the 16C Emulator module on the 41 is a much more convenient tool, with a more sophisticated user interface and rounder function set - not lacking any functionality from the original machine.

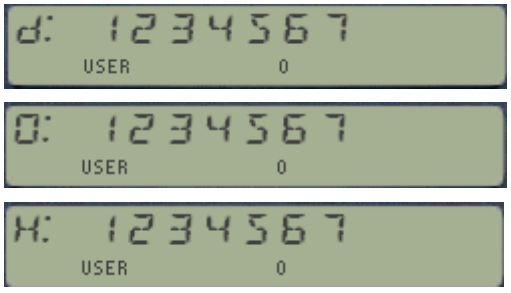
Automated Base Conversions: the four modes.

There are five base modes on the 16C Emulator: Binary, Octal, Decimal, Hexadecimal and Floating Point. By default the floating point mode is pre-selected upon initialization, i.e. the first time the calculator is started with the 16C Module plugged in. There will be no value displayed while the machine is in **FLOAT** mode.

The number conversion between the different bases is performed automatically as you select the base mode of choice. There is therefore no need to exceute any function for visualization – just change to the base of choice using one of the four base mode functions: **BINM**, **OCTM**, **DECM**, and **HEXM**. These are located in the top row on the 16C keyboard, assigned to the [B], [C], [D], and [E] respectivelly.

Note: Another way to change the base mode is using the **ΣMOD** launcher – which will be described later in this section.

The display always shows the base digit on the left, so you can tell which based it is expressed on. Note that the values in the 16C stach will not change when you modify the base mode: they are in binary and BCD as explained before, and the value display routine will represent them in the appropriate base as per the current selection.



These three numbers are indeed very different from each other – the base identifier gives them away.

Don't forget to change the default mode to a digital base; no display will occur in FLOAT mode.

3.1.1. Number Entry on the 16C Stack.

By default the 41 keyboard knows nothing about the 16C module. The standard functions are always available for real-number operation (call it the FLOAT mode if you wish). This is important to remember, as it imposes some discipline on the user to differentiate them from the 16C-version of the same functions – for instance for number entry and stack handling.

For example, pressing "1234" , ENTER^ pushes the real number 1,234 into the Y-register but it does nothing good to the 16C stack at all – just the opposite!

For a proper 16C value entry you must use **16NPT** at all times – even in its quick-entry and shortcut modes. Thus the right keystroke sequence will be: **16NPT**, "1234", ENTER^.

Not much more elaborate, as it only requires the 16NPT as a prefix. This function will lift the 16C stack automatically so no need for a final **16ENT^** at the end in this example.

Similarly other stack manipulation and memory exchanges need to use the 16C-versions instead of the "native" standard ones. Here is where the **16C** keyboard comes to the rescue, as it has most of them pre-assigned to their logical positions (like **16STO** in the STO key, **16RDN** in the RDN key, etc). All you need to remember is *always press the 16C launcher key first*, then the 16C function to complete the action.

Using the **16C** launcher is a more convenient method than populating the 41 keyboard with multiple standard key-assignments for three reasons:

- It doesn't prevent the standard functions from being available in USER mode
- It allows direct access to both main functions and sub-functions equally
- It doesn't take extra memory registers to hold all those many key assignments

However if those points are not an issue you can always re-configure the entire 41C keyboard using **ASN** to map the main functions (won't work for sub-functions) as you find it more appropriate.

Entering lower-bit values with **LOW16^**

As an alternative to **16NPT** you can also use sub-funtion **LOW16^** for a quick-entry mode of values in the lower-bits half-register. With this method you enter the number directly in the X-register instead of the ALPHA registers to hold the characters.

Obviously this only allows introducing digits 0-9 since the standard X- stack register is used. Besides that, the value entered will be normalized to the base and word size conditions in effect by the function, so that the end result will comply with the status of the machine.

Examples.: with word size = 16 and HEX mode selected

12345, **16$** "LOW16^" => "H: 3039"
1234, **LASTF** => "H: 4D2"

But with word size ws=8 and BIN mode selected instead:

12345, **16$** "LOW16^" => "b: 111001" , which corresponds to 57 in decimal – i.e. the value has been truncated to 8 bits

Note: pressing the "digit-pad" in program mode (**16C** plus number key) is the best shortcut to enter **LOW16^** in program mode; just make sure the number is already input in the previous program line.

3.1.2. Flags as Mode Semaphores.

Personally I always thought that one of the shortcomings on the original machine is that it offers no visual information for the currently selected signed mode. Whether it is unsigned, 1's or 2's complement there's no indication on the display to help you interpret the results – which believe me, there will be differences depending on the current setting. As a consequence I need to use the STATUS function very frequently just to see the mode, not very efficient in my mind.

On the 16C Emulator this is always shown by the first three user flag annunciators, " 0", "1", and "2". At all times one of those three will be set to show you the current complement mode, where zero means unsigned mode. They act as semaphores more than programming flags, and while you can manually changed them using the 41 SF/CF functions it is strongly recommended you don't do so. Some functions rely on their status during intermediate calculations, and besides they'll be changed back by the 16C Emulator at the first opportunity to syncronize with the complement mode set.

In other words, flags 0,1, and 2 are reserved as they are taken over by the 16C Emulator in ther role of signed/unsiged mode semaphores.

The example below shows the decimal representation of H: 9000 in 1CMP and 2CMP modes for a word wsize of 16 bits. Can you tell at a glance which one is which?

Carry and Out of Range flags. (CY & OOR)

The original machine uses flags 4 and 5 for the Carry and Out of Range conditions respectively. The display shows "C" for Carry set and "G" for OOR set, which therefore are matched to flag 4 and 5.

On the 16C module however the flags used are 3 for Carry and 4 for OOR – obviously those are also shown in the annunciators area of the 41 display so they were the logical choice. As to why carry is 3 and not 4 as in the original machine, well we went with the rhyme as opposed to the reason this time.

CY and OOR will be set and cleared during the execution of numerous functions, summarized on the table below. In general the CY management is identical to the original machine but the Emulator applies a more extensive rule for OOR, in that there are additional instances besides the math functions that also modify OOR. This prevents confusing interpretations of "why is OOR set now" as a left-over from several operations before.

In other words the OOR flag is triggered more frequently on the emulator than it is on the original machine, like for instance when recalling a number from memory using 16RCL or another 16C stack function (16RDN or similar), in the event that the value being placed in the 16X register is too large for the current word size – i.e. the ws had changed since that number was first stored in the other register.

Note: For more on the CY and OOR flags, you should also refer to the Diagnostics section for flashing messages on Carry and Out-of-Range conditions, user-selectable in a configurable optional mode.

The table in next page summarizes all functions impacting the status of CY and OOR flags:

Function	Carry	Out of Range	Remarks
16+, 16-	yes	yes	|Result| > |max(ws)|
16*	no	yes	Result > max(ws) => OOR
16/	yes	yes	RMD#0, => CY
16SQRT	yes	no	RMD#0, => CY
16X^2	no	yes	Uses 16Y and 16X regs
16CHS, 16ABS	no	yes	*very* CMP-dependent
DBL*	no	cleared	y * x -> (X & Y)
DBL/	yes	cleared	(y & z) / x -> X; RMD#0 => CY
SL(N), SR(N), ASR	yes	no	may push msb/lsb => CY
RL(N), RR(N),	yes	no	may push msb/lsb => CY
RLC(N), RRC(N)	yes	no	may push msb/lsb => CY
16X<>Y, 16X<>,	no	yes	16X > max(ws) => OOR
16RCL, LST16X	no	yes	16X > max(ws) => OOR
16RDN, 16RUP	no	yes	16X > max(ws) => OOR
CL16X, CL16ST	no	cleared	
16WSZ	no	yes	16X > max(ws) => OOR

Table 3.1. Functions affecting the status of CY and OOR flags.

- Blue font functions denotes additional OOR conditions beyond the original 16C machine.
- **SLN** and **SRN** are new additions in the emulator. They behave like the rotation counterparts and only set/clear CY on the last position shifting.
- max(ws) is the maximum value that can be represented within the selected ws, max(ms) = 2^ws -1. See appendix A1 for a complete table, and sub-function **WSMAX** for their calculated values.

No Leading Zeros flag. { LDZER }

Since flag 3 is reserved for Carry that means the "Leading Zeros" functionality from the 16C is not available on the emulator in the same way – zeros are always omitted by default as it was described in the data input & ouptut sections of this manual. Space is at a premium on both ALPHA and the LCD so it didn't seem to be a good idea to use it with non-relevant zeros. The only logical and needed exception is during the digit input process in **16NPT**, which allows for the first digit to be a zero.

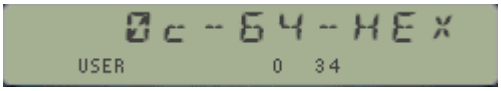
You can however use the subfunction **LDZER** to shows the value in 16X including the leading zeros; as a function of the base and the word size. Like it is the case in the original machine this functionality is not available in Decimal mode (where the actual number of digits depends on the entered values). It is also somewhat limited by the maximum length of the ALPHA registers, so it's not recommended you use it for long binary values (all other cases will fit).

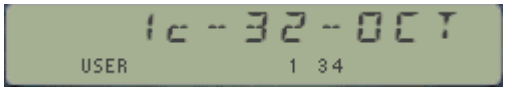
Examples: show the leading zeros for the OCT value 13 with ws=13, then changed to HEX:

3.3.3. What's the Status?

The **STATUS** function is meant to show the current configuration of the emulator settings. Like in the original machine the display includes the complement mode and the word size, but contrary to it the flags information is replaced with the currently selected base. This should not be a shortcoming considering that the status of the relevant system flags 0-4 is always shown in the annunciators section of the LCD display, thus they are visible at all times.

Taking advantage of the alphanumeric capabilities the complement mode is shown as "0c", "1c", or "2c". Likewise the selected base is spelled out as mnemonic (BIN, DEC, OCT, HEX, or FLT). The text is right justified and will stay in the display for a short while before the current value in the 16X register is shown again.





The examples above both show the machine recently had both Carry (user flag 3) and Out-of-Range (user flag 4) conditions. You can see that the complement mode matches the status of flags 0-1-2.

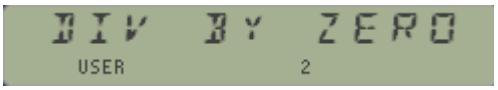
Flashing Functions.

Some functions will flash the result for a while and then revert to showing the current value in the 16C register. For **STATUS** this is also the case on the original 16C, and like on it you can hold the flashing display by holding any key - after you have allowed it to be presented, or otherwise all you'll get is the "NULL" message from the 41 OS.

Besides **STATUS** the other flashing functions are **#BITS**, **WSFIT** and **16WSZ?** – the last two being new additions to the function set, which will be described later on.

New (Flashing) Error Conditions.

The Division functions may show the error conditions to denote a math error condition – either a division by zero in **16/** or a quotient result too large for the selected word size in **DBL/**



These error messages will briefly show in the display, but the original arguments will remain in the 16C stack. If this occurs during a program the execution will halt showing the familiar "DATA ERROR" message.

3.1.4. Prompting Functions.

The HP-41 features a user interface design more advanced than what the original 16C has. One of the nicer features is the prompting functions, whereby the function's argument is entered at the prompt in manual mode.

Whenever possible we have favored this implementation over the usage of the 16X register for function parameter, saving so keystrokes and simplifying the data entry sequence – as this approach removes the need to use the **16C** keypad or **16NPT** to enter the parameters.

This is *only applicable to the operation in manual (RUN) mode*. In Program mode the functions behave in the same way they do on the original 16C machine.

The new prompting functions are shown in the table below:

Function	Parameter		Function	Parameter	
MASKL _ _	1 to ws		RRN _ _	1 to ws	
MASKR _ _	1 to ws		RRCN _ _	1 to ws+1	
Sb _ _	0 to ws-1		RLN _ _	1 to ws	
Cb _ _	0 to ws-1		RLCN _ _	1 to ws+1	
b? _ _	0 to ws-1		16WSZE _ _	0< ws <65	
SLN _ _	1 to ws		WINDOW _	0<= w# < 8	
SRN _ _	1 to ws				

Common implementation features to all these functions are as follows:

- Parameter entry requires two digits, always assumed to be decimal numbers irrespective of the selected base mode. You can use the "soft" keys on the two top rows for parameters 1 to 10.

- The prompts will stay put (i.e. the function will ignore the input) for parameters larger than the maximum word size (64).

- A warning message reminding of the current word size "WS= nn" will be shown if the parameter entered is larger – In a running program the message shown will be 'OUT OF RANGE' in those instances, and the execution will halt at the current program line.

- Entering "00" will toggle between complementary function pairs, i.e. change MASKL into MASKR, RRN into RRCN, RLN into RLCN, SLN into SRN, and vice-versa. This does not impact the bit selection functions Cb, Sb, and b? – for which zero is a valid input value.

- Pressing [SHIFT] will activate the INDirect facility – i.e. the parameter is retrieved from the standard data register entered at the prompt. No support for STack registers is provided, so do not use IND ST_ even if you can bring that option to the display.

- When you enter the functions in a program the prompt will be discarded by the OS – so you can fill it with any values.

- **In a running program** the parameters are taken from the 16X register –the same as in the original machine. Just fill the prompt with any values when you enter the function – they'll be ignored by the OS at that point. Note that in program mode a zero or values larger than the current word size will also trigger an out of range condition.

3.1.5. Test Functions Launchers.

You may have noticed the conspicuous absence of the test conditional functions from the 16C overlay – or almost, since there above the [EEX] key are to be found the two test launchers, **X?Y** and **X?0** – very much following the design used by other calculators, like the HP-32S.

All individual test functions are in the auxiliary FAT, thus they're implemented as sub-functions. In fact that's also the case for the **X?0** launcher itself – even if that fact is totally transparent to the user and on the overlay.

There are six different tests for XY conditions, plus another six for zero conditions. Each group is split into two screens, with three choices on each of them as shown in the pictures below. You can use the [SHIFT] key to move between the screen choices within each launcher, and the "anchor" key to change the launcher type back and forth:

And pressing the "anchor" key [**A**] changes to the zero-test groups:

In all cases the selection is made using the top row keys [**C**], [**D**], and [**E**] – You can also hit the "anchor" key [**A**] to toggle between the **X?Y** and **X?0** launchers right from within them !

Being subfunctions adds no restriction to the testing functionality, even if an index line number is required in a program to identify which one is to be used. As it is known, the non-merged functions cannot be located *after* a test conditional (or otherwise the skip-if-false rule will jump into the middle of both lines) – but there's nothing preventing them to be placed *before* a normal program line. The non-merged functions take care of updating the program counter to always ignore the index# line, so the YES/NO, do-if-true rule is perfectly applicable in this case.

Examples:

a. Correct utilization

```
01 16#
02  6
03  GTO 01
04  GTO 02
```

b. Incorrect utilization

```
01  FS? 25
02  16#
03  6
03  GTO 01
04  GTO 02
```

That's the reason why the tests have all six cases, including ">=", which wouldn't be possible to do using a chained double conditional like it is done for the standard OS functions.

The table below shows the sub-function indexes (in decimal) used for the test conditionals:

Test Criteria	X vs. 0	X vs. Y
=	6	12
#	7	13
>	8	14
>=	9	15
<	10	16
<=	11	17

3.1.6. ISZ/DSZ and Function Parameters.

The HP-41 has its own implementation of the index-controlled functions **ISG** and **DSE**, more flexible than those in the HP-16C and HP-15C – which use the HP-67 model with **ISZ** and **DSZ** instead, whereby a unique indirect register is used and the index value is always made with zero.

For convenience the emulator includes **DSZ** and **ISZ**, which use the R00 register to hold the "indirect" variable "I ". Therefore you won't need to worry about converting the format for 16C program compatibility using **ISG** and **DSE**. Notice however that this implementation still uses a standard register (R00) and not a 64-bit logical register like it is the case for the 16C stack or the other registers as accessed by **16STO** and **16RCL**.

While it is safe to assume that loop counters and other parameters won't exceed the 32-bit limit, you can always "convert" the index into a 64-bit format using **LOW16^** in case that is required.

Similarly, the parameter for **16WSZE** can only go up to 64 so it's a bit of an overkill to allocate 64 bits for that one too; therefore you can just use a standard value in X and **16WSZ** will accept it as a valid input. Remember however not to disturb the 16C stack by doing so!.

Contrary to this situation, the masking, bit shifting and rotation functions expect 16C-formatted values when used in a program for the number of positions (or number of bits in the MASKL/R case) – thus you shouldn't use the standard X-reg workaround with them. As a reminder, the three proper ways to do it are:

- a string value in ALPHA plus **16NPT** (and optionally **16APN**), or
- a decimal value in real-stack X register plus **LOW16^**, or
- a value from **16RCL**, **16X<>**, or any other 16C stack operation.

Registers and Word Size changes.

There is no effect of a word size change in the data stored in the data registers. This is different from the real 16C machine, which adjusts the values in memory to fit the currently selected word size – spilling over adjacent registers in case of a wordsize decrease and splitting across registers in case of a wordsize increase.

Put in another words, the size of the storage registers in the HP-41 is fixed, always 56 bits whereas on the 16C it is a variable number defined by the smallest multiple of 4 bits (half-bytes) equal to or greater than the current word size.

Depending on your programs and needs that may be a fundamental difference or just a negligible detail – but nevertheless it is important to be aware of if for the cases where this becomes a relevant consideration. Suffice it to say that the memory allocation is a very particular affair on the 16C, much more intricate than on any other HP calculator to say the least.

3.1.7. Square Root and Square Power. { **16SQRT** , **16X^2** }

The Square root function is a bit of a hybrid in that is uses the native OS routines to calculate the result. This is clearly a way-around approach that works just fine for input values lower than 2^33 but that needs to be adjusted for larger values of the input parameter.

The adjustment is done in a short FOCAL code stub triggered by the function itself when required. It simply checks if the square power of the result matches the input parameter. If it does then it's a perfect square that needs no adjustment. If it doesn't then it may need subtracting one to the result, and it will always have to set carry.

The only caveat to this approach is that the original input value is not left in the LST16X register – but in the 16Y level of the 16C stack. In any case the final result will only be shown in manual mode, not if the function is executed in a program

The program below illustrates the method used for the adjustment of the result calculated by the 16SQRT function. The actual implementation is more clever and splits the execution between an intial MCODE part and a final FOCAL adjustment only done when needed.

1	**LBL "64SQRT"**	
2	**CF 05**	
3	**CF 06**	
4	**32SQRT**	*32-bit square root*
5	**LOW16^**	*replicate result in 16C stack*
6	**LST16X**	*recall input x*
7	**16RDN**	*place it in 16T level*
8	**16***	*calculates sqrt(x)^2*
9	**16RUP**	*recall x to 16X*
10	**16X#Y?**	*is x # sqr(x)^2?*
11	**SF 05**	*yes, set flag 5*
12	**16X>Y?**	*is x > sqr(x)^2?*
13	**SF 06**	*yes, set flag 6*
14	**LST16X**	*recall sqrt(x) to 16X*
15	**FC? 05**	*were they different?*
16	***GTO 05***	*no, the result was ok*
17	**FS? 06**	*was it greater?*
18	***GTO 06***	*no, skip adjustment*
19	**1**	*yes, subtract one*
20	**-**	*(always < 2^32)*
21	**LBL 06**	
22	**SF 03**	*sets carry*
23	**LBL 05**	
24	**SHOW**	*show result*
25	**END**	*done.*

The square power **16X^2** is a subfunction available for keytroke convenience, as it is assigned to the X^2 key on the 16C keyboard. It uses the main 16* code with 16Y equal to 16X, thus it is completely equivlent to the sequence { **16ENT^**, **16*** }. There is no byte savings in a program using either of those approaches- 4 bytes will be used.

Therefore you need to keep in mind that two levels of the 16C stack will be used. Note that following the standard conventions the input parameter is left in the LST16X register.

3.1.8. A few Examples: Gray Code, Bit Extraction, Add w/ Carry

The following examples are taken from the HP-16C article published in the May 1983 HP-Journal issue. With them you should get familiar with the way the emulator functions are used to prepare 16C-like programs on your HP-41. We're sure you'll appreciate having the function names shown as opposed to their keycodes on the original machine - and enjoy seeing the goose flying.

a. Binary-to-Gray and Gray-to-Binary conversions

1	LBL "GRAY"	7	LBL "BIN"
2	16ENT^	8	16ENT^
3	SR	9	LBL 02
4	XOR	10	SR
5	SHOW	11	XOR
6	RTN	12	LAST16
		13	16X#0?
		14	GTO 02
		15	16RDN
		16	SHOW
		17	RTN

Note that the test function 16X#0? Really corresponds to the combination of the two program lines:

16# and
7

Example: convert b: 11010 to Gray code and back to binary.

Keystrokes	Result	Comment
BINM	b: xxxxx	current 16X content
16NPT, 1, 1, 0,1,0, R/S	b: 11010	enters binary value in 16X
XEQ "GRAY"	b: 10111	Gray equivalent
XEQ "BIN"	b: 11010	Original value back

b. Bit Extraction and Addition with Carry

1	LBL "bXT"	1	LBL "16+C"
2	16RDN	2	CF 03
3	RRN	3	*"0"*
4	16RUP	4	16NPT
5	LAST16X	5	RLC
6	16-	6	16+
7	*"1"*	7	CF 05
8	16NPT	8	FS? 03
9	16+	9	SF 05
10	MASKR	10	16+
11	AND	11	FS? 05
12	HEXM	12	SF 03
13	SHOW	13	SHOW
14	RTN	14	RTN

Note the usage of 16NPT to enter values to the 16C register, as shown in lines 7/8 of "bXT" and lines 3/4 of "16+C".

Note also the carry flag is "3" on the emulator, not "4" as in the original machine.

Apart from that the programs are practically identical to the original ones on the real 16C machine.

Examples: Extract bits 2-5 from the value H: 39 (or b: 111001)

Keystrokes	Result	Comment
HEXM	H: XXXX	current 16X contents
16NPT, 3, 9, R/S	H: 39	enters 39 in 16X
16C, 2	H: 2	lifts 16C stack
16C, 5	H: 5	lists 16C stack
XEQ "bXT"	H: E	or b: 1110

3.2.- New functions not present on the original 16C.

This section needs to start describing the other function launchers – one of the more relevant additions to the functionality of the emulator not available in the real 16C machine.

There are two kinds of launchers: those that group functions by complementary operation (like **ΣROT** and **ΣSHF**), and those that do it according to a functional criteria, (such as **ΣMOD, ΣBIT, ΣLEFT** and **ΣRGHT**). Note the consistent use of the sigma letter in their names to denote a launcher funtion.

3.2.1. Rotations Launcher – { ΣROT }

This launcher groups the 8 rotation functions into two screens, one for operation excluding the Carry bit and another for the operation including it. Once it is up on the display you will use the [SHIFT] key to toggle between each screen, as shown below:

Where the only visible clues are the SHIFT annunciator and the "C" added to the screen id# on the left. The function table is below:

	RL	Rotate Left		RLC	Rotate Left thru CY
	RLN _ _	Rotate Left n positions		**RLCN** _ _	RLC n positions
	RRN _ _	Rotate Right n positions		**RRCN** _ _	RRC n positions
	RR	Rotate Right		**RRC**	Rotate Right thru CY

3.2.2. Shiftings Launcher – { ΣSHF }

This launcher groups 4 bit shifting functions in the first screen, plus another 4 bit-manipulation functions in the second. Once it is up on the display you will use the [SHIFT] key to toggle between each screen, as shown below:

	SL	Shift Left		**DGLJ**	Digit Left Justify
	LN _ _	Shift Left n positions		**LJY**	Left Justify
	RN _ _	Shift Right n positions		**RJY**	Right Justify
	SR	Shift Right		**ASR**	Arithmetic Shift Right

Remarks:

- Both the Rotations and the Shifting launchers expect you to choose the option using the top row keys [**B**] to [**E**] as per the screen layout.
- Hitting the "anchor" key [**A**] (in the non-shifted screen) will move back and forth between these two launchers, the Rotation and the Shifting screens.
- Pressing the back arrow keys cancels the function and displays the current value in the 16C register again.

3.2.3. System Modes Launchers – { ΣMOD and ΣBIT }

Moving on now to the "functional criteria" launchers, they have in common that the prompt includes the different choices as a string of letters separated by colons, and the selection is made using the initial letter of the function chosen.

The first two group the signed modes, the base modes, and other system configuration controls – very fundamental part of the system indeed. **ΣMOD** is assigned to the USER key on the 16C keyboard, and shows the following teo screen when called – toggled with the [SHIFT] key as usual:

Unshifted screen.

Roughly speaking the left half of the LCD is for the base modes (Binary, Octal, Decimal, Hex and Floating Point Mode) whereas the right half of the LCD is for the signed mode (**UCMP**, **1CMP** and **2CMP**) plus the word size setting (**16WSZE**, **16WSZ?**). The question mark is for **STATUS**.

	ΣMOD				
	BINM	Binary Display		UCMP (**0**)	Unsigned Mode
	OCTM	Octal Display		**1**CMP	1's Complement mode
	DECM	Decimal Display		**2**CMP	2's Comlpement mode
	HEXM	Hexadecimal display		16**W**SZE _ _	Sets word size
	FLOAT	Floating Point mode		16W**S**Z?	Shows Current ws
	-	Separator - shows ©		STATUS (**?**)	Shows the Status

Shifted sscreen:

Here too the left part is for general configuration and information functions, whilst the right part includes bit and digit reversal and sums - plus the three general bit manipulation functions.

	ΣBIT				
	BASE?	Recalls current base		**R**EV	Bit reversal
	16KE**Y**S	16C key assignments		DGD**Σ**	Decimal Digit Sum
	TS/L	Toggle Silent/Loud		**#**BIT	#Bits set (*)
	LD**Z**ER	Shows Leading Zeros		**C**b _ _	Clears bit
	-	Separator - shows ©		**S**b _ _	Sets bit
	DGRV	Digit Reversal		b**?** _ _	Is bit set?

(*) Use the "H" character for the hash/pound symbol - #

One of the main advantages of these launchers is that they provide direct access to both main and sub-functions in their choices. You should also note that the functions **16#** and **16$** are also included in the choices even if not shown in the LCD – just by pressing the USER and ALPHA keys as well.

So there you have it, perhaps a bit of repetition but you have it both ways so no excuse for not being able to access the functions or subfunctions in a split second anymore.

3.2.4. Left and Right Launchers – { ΣLEFT and ΣRGHT }

The last two group many shifting and rotation functions together using the geometric position as a criteria – as opposed to the specifit bit manipulation action as in the previous cases. You can think of these two launchers as the two personalities of the same function, and as you surely have guessed already you'll use the [SHIFT] key to toggle between them at will.

There are 9 functions on each screen, as shown on the function tables below:

	ΣLEFT _			ΣRGHT _	
	LJY	Left Justify		RJY	Right Justify
	REV	Reverse Bits		ASR	Arithmetic Shift Right
	MASKL	Mask Left		MASKR _ _	Mask Right
	SLN	Shift Left n-positions		SRN	Shift Right n-positions
	RL	Rotate Left		RR	Rotate Right
	RLN	Rotate Left n-positions		RRN	Rotate Right n-positions
	RLC	Rotate Left thru CY		RRC	Rotate Right thru CY
	RLC#	RLC n-positions		RRC#	RRC n-positions (*)
	STATUS (?)	Shows the Status		STATUS (?)	Shows the Status

(*) Use the "H" character for the hash/pound symbol - #

ΣLEFT is a main function but **ΣRGHT** is located in the Auxiliary FAT, with index# = 2

Note also that the main four launchers are interconnected and can be navigated sequentially using the XEQ key. Refer to the chart in next page for a complete representation of the options.

Launchers as sub-functions.

There are four launcher functions located in the auxiliary FAT, thus implemented as sub-functions in the 16C Emulator module: **ΣSHF, ΣBIT**, **ΣRGHT**, and **X?0**.

Because sub-functions are always programmable (i.e. cannot be declared as non-programmable), when you execute them in program mode the function itself will be entered into the program. This means you cannot use them this way in program mode to directly access their menu choices as it happens in manual mode.

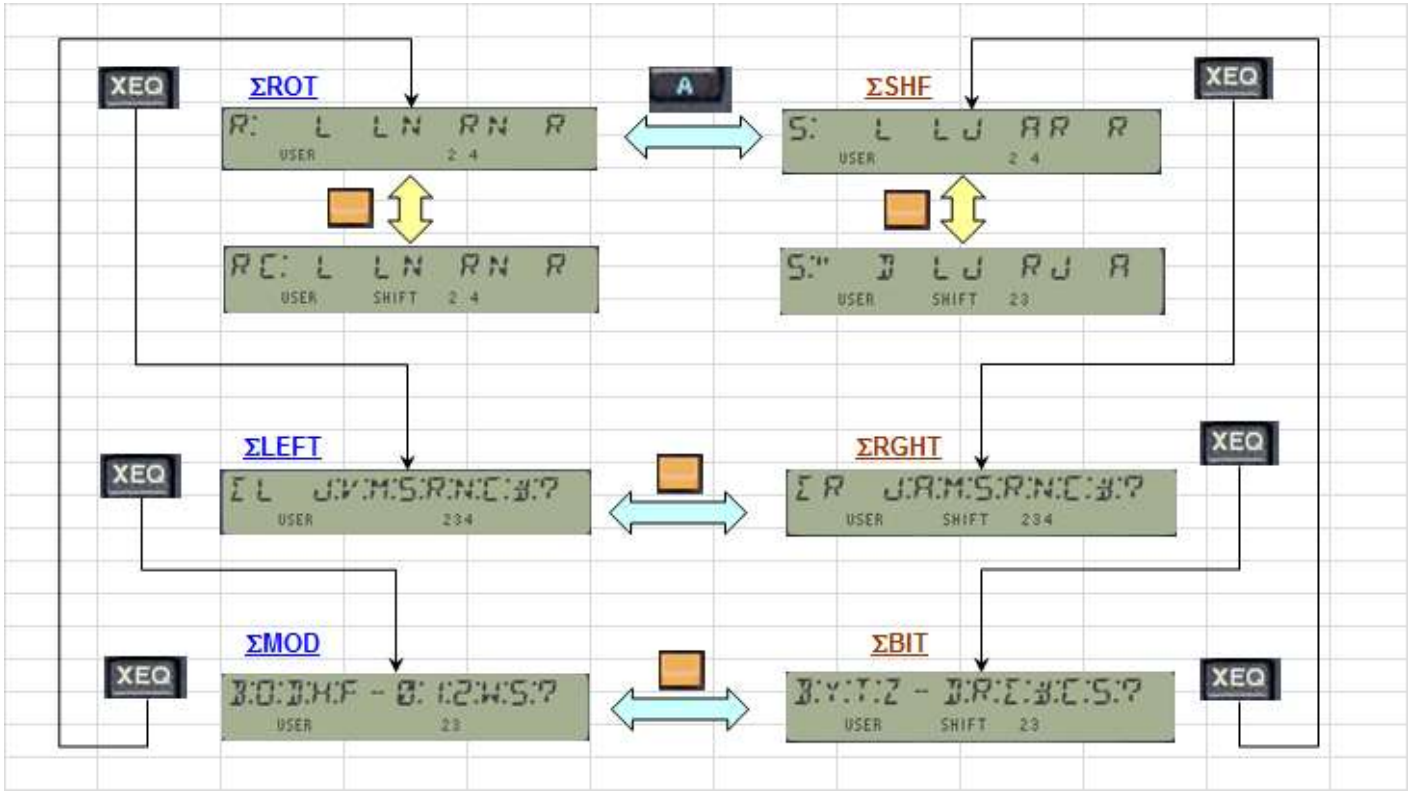
To work-around this limitation you can use their "parallel" launchers - which as main functions are properly declared as non-programmable - and toggle their functionallity using either the SHIFT key and/or the anchor key [A], as follows:

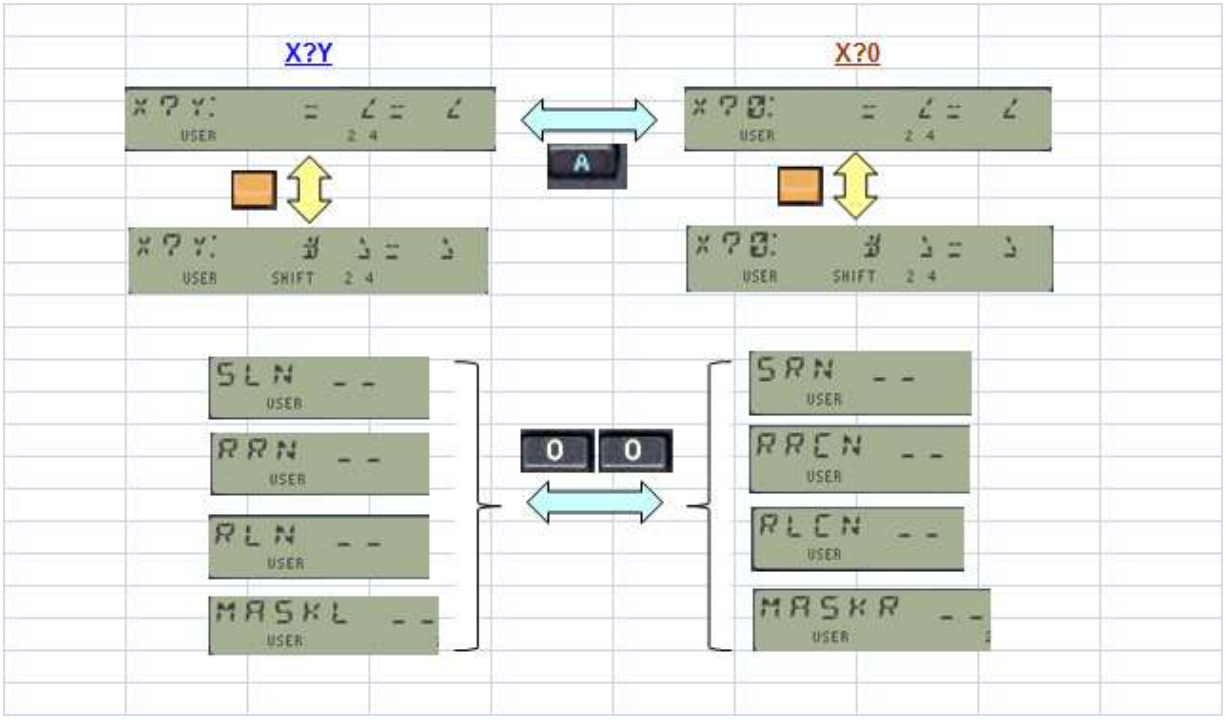
- Use **X?Y**, [SHIFT] -> for **X?0** options
- Use **ΣLEFT**, [SHIFT] -> for **ΣRGHT** options
- Use **ΣROT**, [**A**], [SHIFT] -> for **ΣSHF** options
- Use **ΣMOD**, [SHIFT] -> for **ΣBIT** options

Naturally you can also access any of their menu choices by calling them individually, using its index or name within the auxiliary FAT – as described in the next pages.

3.2.5 Launcher Maps – Navigating the Function Shortcuts

A picture is worth ten-thousand words…





3.3. Remaining functions not on Launchers.

As there are several other functions not included into any launcher, one would assume that there must be some other way to access them. After all they can also be very useful either in manual mode or included in your program, and who knows, some of them can even become your very next favorite one.

Those amongst you familiar with the SandMath or PowerCL modules would already know the answer is in the sub-function execute functions, which for the 16C Emulator are **16#** and **16$**.

There are three ways to execute any sub-function:

- by name, spelling all letters at the "16$ _" prompt – For your convenience the ALPHA mode is activated by **16$** so you can start spelling the function directly, saving another pressing of the ALPHA key – (like it is needed for COPY for example).

- by its index, entering the number at the "16#_ _ _" prompt (in decimal) - the subfunction name is briefly shown in the display when it is entered using its index at this prompt , as well as during a single-step execution in a program. This provides visual feedback to the user as to whether the function was that intended to use.

- by direct enumeration using **FCAT**, hitting [XEQ] when the sub-function name is shown and the enumeration is paused (single-stepped).

In terms of the 16C keyboard, you can access **16#** pressing [PRGM] and **16$** pressing [ALPHA] keys respectively at the **16C** prompt (and some other launchers as well) – all conveniently layed out for you.

Note: Even if the sigma character "Σ" can be typed during the **16$** prompt, it however won't be recognized by the name search routines due to some conflicts in the character value assignment. You need to use the "N" character instead – or the **16#** function followed by the sub-function index. This only impacts the sub-function **DGDΣ** and the three sub-function launchers covered before.

3.3.1. Last Function functionallity and Programability.

Also common to the other modules (not surprisingly since the same routines in the Library#4 are used), the function is either executed in manual mode, or automagically entered as **two** program lines in PROGRAM mode. Furthermore the subfunction code is stored in the LastFunction buffer so it can be re-executed pressing **LASTF** on the 16C keyboard (Radix key at the 16C_ prompt).

Note that **16$** can also be used to execute functions in the main FAT, or even functions located in other plug-in modules: if the function name is not found in the auxiliary FAT the search continues automatically through all the modules plugged on the 41 system; and only if no match is found the 'NONEXISTENT' error message is displayed.

Obviously there's a noticeable time penalty associated with all this - but one that it's totally unpercieved on the 41-CL set in TURBO 10 or higher in case you wonder.

LASTF Operating Instructions

The Last Function feature is triggered by pressing the radix key (decimal point - the same key used by LastX) while the launcher prompt is up. This is consistently implemented across all launchers supporting the functionality in all four modules – they all work the same way.

When this feature is invoked, it first shows "LASTF" briefly in the display, quickly followed by the last-function name. Keeping the key depressed for a while shows "NULL" and cancels the action. In RUN mode the function is executed, and in PRGM mode it's added as two program steps if programmable, or directly executed if not programmable.

If no last-function yet exists, the error message "NO LASTF" is shown. If the buffer #9 is not present, the error message is "NO BUF" instead.

The LastF buffer is maintained automatically by the modules (created if not present when the calculator is switched ON), and its contents are preserved while it is turned off (during "deep sleep"). No user interaction is required.

The buffer reserves one register for each of the four modules that have sub-functions, plus the header also stores the 41Z last-function - which is always in its main FAT. Therefore up to five last-functions can be simultaneously available at any given time. A total of five registers are used, as follows:

Register	Used for:
b4	SandMatrix fcn id#
b3	SandMath fcn id#
b2	PowerCL fcn id#
b1	16C Emulator – Time-based Seed (RND)
b0	Header – w/41Z fcn id#

Not bad for a single-line, 12-chars LCD machine from 1979, won't you agree? Which once again proves the adagio "*it's not the size of the wand what matters but the skill of the wizard who uses it*…"

3.4.- Individual Description of the new functions.

The remaining sections provide a succint description of the added functions not included in the original 16C calculator and not covered already in previous chapters of this manual. Some are little embellishments of standard 16C functions, or natural extensions of the same ideas that probably weren't included in the original machine due to space constraints. They are located in the auxiliary FAT and therefore you need to use the **16#** or **16$** launchers to execute them.

3.4.1 Negative Logic Functions. { **NAND** , **NOR** , and **XNOR** }

Not needing much as description, these three round up the set of logical functions and save you from having to NOT the result of their positive counterparts.

Examples. Here's a table of direct results with ws=32 and 16x=1, 16Y=0

Value	NAND	NOR	XNOR
Unsigned	d: 4294967295	d: 4294967294	d: 4294967294
1CMP	d: -0	d: -1	d: -1
2CPM	d: -1	d: -2	d: -2

3.4.2. New Word Size related functions. – { **WSFIT** , **WSMAX** , **16WSZ?** }

- **16WSZ?** is a flashing function that in manual mode shows the current word size briefly on the display, and then enters that value in the 16X register - peforming a stack lift. You can maintain the flashed message up holding any key once it has been shown – or it'll just NULL itself out.

- **WSMAX** simply returns to the real X-register the maximum value that can be represented with the currently selected word size. In math terms, this is calculated by the formula:

  Wsmax = [e^(ws*Ln 2)] – 1

- **WSFIT** will change the selected word size to the needed number of bits to represent the current value in the 16X register. This has two possible uses, one to downsize the word size in case the value in 16X is smaller than the maximum one (i.e. eliminating thos bits used by the leading zeroes), but another one is to increase its size as per the binary value exisiting in the 16X register – which in some instances may be a superset of its visual representation made by SHOW and WINDOW.

Example. With ws=32 calculate the square of H: 123456.

16NPT "123456", **16X^2** returns H: 66CB0CE4 and sets the OOR flag.
Pressing **WSFIT** shows the message "WS=41" followed by H: 14B66CB0CE4

3.4.3. Bit Reversal function – { REV }

Often it's needed to reverse the bit sequence of a word – be that because of incompatible data transfer protocol conventions or for another legit reason. This is no surprisingly the subject of applied math and sophisticated algorithms exist – but this implementation follows a sequential alteration of the bits to build a mirror-image of the initial word.

Note that the reversion is made on the complete word size, i.e. taking into account the leading-zeros as well. There are two ways to circumvent that if not desired:

1. Execute **WSFIT** first to adjust the word size to the number of relevant bits, then call **REV**. Realize that the word size has been changed and may need changing back.

2. Call **REV** and then use **RJY** on the result to get rid of those reversed leading zeros after they're reversed into the LSB positions.

Example: set ws = 12, HEX mode. Get the bit reversal of 9

16NPT, 9, => H: 9 (or b: 00001001)
REV => H: 90 (or b: 10010000)
RJY => H: 9 since 0x9 is a "polindrome" value, so to speak

Example: Verify that the bit reversal of 0xD9 with a word size ws=8 is 0x9B

Which is easy enough to check in binary base, but pretty challenging in decimal with 2's complement set, as a manner of example:

3.4.4. Right and Left Justification. - { LJY , RLY }

There is no Right Justify function on the original 16C but somehow it felt just natural to include that function to complete the set, if only for symmetry sake. But there's also some slight difference in the way **LJY** the Left Justify function works.

The 16C Emulator versions return the left- and right-justified values to the 16X register, and the number of positions needed to do the justification in the 16Y register – exactly opposite to the original **LJ** function on the machine.

Not much of a difference, as executing **16X<>Y** will bring things back to the original shape – but nevertheless important for you to be aware of in case you're using programs copied from the original machine.

3.4.5. Shifting multiple Positions – { SLN , SRN }

The original 16C includes one-position shifting functions **SL** and **SR**, which on the emulator have been moved to the Auxiliary FAT as subfunctions. Their place in the main FAT has been taken by n-position versions of the same functiions, which as a particular case can also perform the single-position. With n=1.

The number of positions is entered in the function prompt in manual mode, or taken from the 16X register when running a program.

In a program any value larger than the current word size or zero will result in a "DATA ERROR" condition, but in manual mode:

- Entering a number larger than 64 will be ignored and the prompt will stay put.
- Entering a number larger then the word size will show the message "WS=nn" and cancel.
- Entering zero at the prompt will toggle between these two functions.

Obviously right-shifting more positions than the current number of bits will result in a zero result. Not so obvious perhaps is the case of left-shifting a number of positions beyond the current word size, which will eventually also result in zero once all bits have been moved off the field.

Notice that when shifting multiple positions the carry flag will reflect the circumstances on the last bit shiting action, and thus not a cumulative effect. This is consistent with the behavior of the n-position rotation functions RLN and RRN.

Bacause the shifted bits are "lost", these two functions are not always complementary of one another. This is different from the bit rotation functions, where the rotated bits are kept within the word and/or CY bit – just in different positions.

Note that when entered in a program it is more byte-efficent to use the n-positions version with the value "1" in the 16X register (three bytes) instead of using the 16# launcher followed by its sub-fuction index (four bytes). The 16C stack conditions however are different in those two cases, so you should choose the better one for your case.

3.4.6. Storing the 16C Stack in Extended Memory. { SAVE16 , GET16 }

You can use sub-functions **SAVE16** and **GET16** to store and retrieve the complete 16C stack plus the auxiliary buffer registers to / from an extended memory file. Note that even if you can have multiple X-Mem files with different 16C stack sets (obviously with different file names), there can only be one on-line at any time.

When you execute **GET16** there's a check prompting for confirmation. Realize that this action will override the existing 16C buffer, replacing it with the data from the X-Mem file. Only the "Y/N" keys are active at this prompt.

Upon termination the function will show the current value in the 16X registers in RUN (manual) mode; either the current one for **SAVE16** or the newly retrieved one in the **GET16** case. Also the mode annunciators 0-1-2 will be changed appropriately if different.

If you're using the OS/X extension module you'll notice that these files will be identified with the character "H" during the CAT_4 enumeration. Also note that 16C stack files are always 25 registers long – 20 for the buffer plus 5 for the {X,Y,Z,T,L} stack.

Notice how the X-Mem file really occupies 28 register in X-Mem, as there are three additional registers needed by the OS to manage it within the X-Mem file system.

The file header register is the second one starting from the bottom. This address can be retrieved using the function **FLHD**, available in RAMPAGE module amongst others.

The buffer address can be obtained using function **BUFHD**, available in the RAMPAGE module as well – with several others for buffer management in case you're interested.

#	X-Mem File	Buffer-11
1	File End marker	-
2	L	-
3	X	-
4	Y	-
5	Z	-
6	T	-
7	F7	F7
8	F6	F6
9	F5	F5
10	F4	F4
11	F3	F3
12	F2	F2
13	F1	F1
14	F0	F0
15	E3	E3
16	E2	E2
17	E1	E1
18	E0	E0
19	B14	B14
20	B13	B13
21	B12	B12
22	B11	B11
23	B10	B10
24	B01	B01
25	B00	B00
26	bHeader	bHeader
27	File Header	-
28	File Name	-

3

4.- DIAGNOSTICS

4.0 Silent and Loud Modes. { TS/L }

Without a doubt the Carry and Out of Range flags are a vital component of the information displayed during the execution of the calculations. However it's not difficult to miss a particular occurrence of these situations, or you may find yourself paying extra attention just to catch possible changes of these flags.

The 16C Emulator offers a "*training wheels*" mode to make those situations easier to remark: each time the Carry or Out of Range flags are set a corresponding message is shown briefly in the display. Besides the visual message also a short tone sounds to alert the user, with a higher pitch for CY and a lower one for OOR.

Note that contrary to the standard 41-OS these messages will flash in the LCD briefly and then they'll go away to show the result of the function executed. We have used the text "OVERFLOW" for the Out of Range warning as it is easier to read during the brief flashing time, and to differentiate it from the floating point error from the native 41 OS. We'll refer to this as the OOR event nonetheless, following the 16C conventions.

Activating the LOUD mode.

The SILENT/LOUD modes are user-selectable executing the sub-function **TS/L** to toggle the active mode. Of course you can also use the numeric launcher **16#**, with index =054. When you do the mode selected is also briefly shown in the display – plus a dual tone if you're toggling to LOUD mode.

The CY/OOR messages "air time" will be variable, as it depends on the subsequent operations performed during the execution of the function. For 41CL users the implementation is compatible with the current turbo setting so you won't be missing them even if the CPU is running at high speeds.

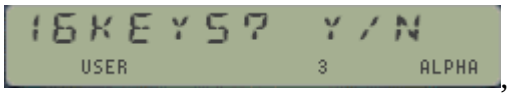
Independently form whether you are a casual user or a seasoned digital design engineer, you may find this functionality useful, neutral, or plain hideous – in which case all you need to do is ignore this section altogether as the factory-default setting is SILENT mode. Go ahead and try it out to get the feeling and decide for yourself.

It comes without saying that the flags annunciators will continue to be displayed as well in Loud mode. Lastly, and as you can expect, the messages will not be displayed when the functions are executed in a runnng program.

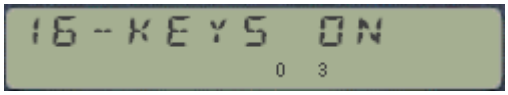
4. 1.- An alternative to the 16C keyboard. { 16KEYS }

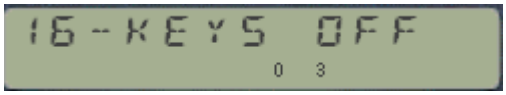
If you prefer a more direct approach to access the 16C Emulator functions in an automated way, the sub-function **16KEYS** will prepare a standard key assignment-based complete keyboard re-definition for all those (main) funcions from the 16C keyboard to be assigned to their corresponding keys.

When executed it prompts for the action to perform, press "Y/N" either to do the assignments or to clear them. You can also cancel at this point pressign the back arrow key. Once the action is completed the function will display the current value in 16X.



,



or:


This method removes the need to press the **16C** "prefix" key each time you need to execute the emulator functions, thus from that perspective is a faster one and perhaps the closest to the original machine. The only requirement is to have USER mode on, and conversely you'll need to turn it OFF when you need to access any of the standard HP-41 functions. Another disadvantage is that no other key assignments are compatible with this mode since all keys have a function assigned.

It however has two important shortcomings:

- No support for the **LASTF** facility or the **16#** and **16$** launchers – since it's not possible to assign functions to the PRGM, USER or ALPHA keys. Note that you can also use the "**-16C_STACK**" function – or XROM 16,49 – to trigger the LASTF functionality. It's easy to do with the **XROM** function in the OS/X module. Also to overcome this deficiency the **16#** function will be assigned to the [RADIX] key.

- No support for sub-functions from the auxiliary FAT - which have been replaced with **16C** itself, so you have a way to invoke them: simple repeat the same action, which the second time will trigger the 16C**-**variant on that sequence of keystrokes.

Remember that executing a function directly via XEQ (or assigned to a key) does not store the function's id# in the LASTF buffer – so even if you can access the LASTF functionallity the buffer contents will only be updated when you use **16C** or other launcher to execute the function.

Both the 16C-prefix Keyboard and the 16KEYS approach use the same 16C overlay shown in page 15 of this manual. Since both are available on the emulator you can choose the one that suits you better - the choice is yours.

4. 2.- A few development aids.

The remaining section of the manual describes a handful of utility functions that were using during the development of the module for testing purposes. Some may be of interest to you if you feel adventurous and decide to explore the 16C Buffer or other more technical aspect of the implementation.

4.2.1. FX Buffer registers handling. { A2FX, CLRFX, EX2FX, FX2EX, FXSZ? }

As the repository of the digits shown in the displaying of the results, the buffer FX registers have a pivotal role in the emulator design. Normally you won't have to worry about their contents – which will be updated by the module's functions and accessed by **SHOW** and **WINDOW**; but should you feel intrigued here are the functions available for the tasks.-

Note that the output of these functions is does not utilize the module's digital facility, but just standard real numbers or even no changes to the display at all.

- **A2FX** – Alpha to FX Registers

  This function writes the current content of the ALPHA registers {M, N, O, P} into the buffer FX registers, starting at the first available position within the FX set (as per the [S&X] field information). Up to 24 characters can be written using this function, but there is no action on the GRAD annunciator in case of overload.

- **CLRFX** – Clears FX registers.

  A complete clear of all eight FX registers, which resets their "active" contents to zero. Register labels will be respected, from F0 to F7 in nybbles <13,12>.

- **EX2FX** and **FX2EX** – Moving data between EX and FX registers.

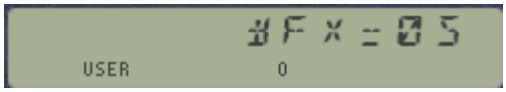
  This pair of functions move the data back and forth between the {E0, E1} registers (in binary form – NNN) and the {F0 – F7} registers. The ASCII digit values in FX are dependent on the current base mode selected.

  Note that even afer executing **FX2EX** the result will *not* be placed in the 16C stack – that is the buffer register b13 and stack X-register.

- **FXSZ?** – FX Registers size.

  This function returns the number of digits currenly used in the FX registers. A maximum of 64 digits is returned (for BIN mode only), sinc each FX register can hold up to eight characters. The status of the GRAD annunciator will be lit if greater than 24. In fact this function is like **ALENG** for ALPHA, but excluding the base id# and leading blank character.

  The result will be pushed in the 16C stack, and brefly shown in a flashing message:



Advanced user's tip: Nothing like a comprehensive RAM editor like **RAMED** in the OS/X module for cursory inspections of all the buffer registers in all their g(l)ory details – even editable if you decide to take a walk on the wild side…

4.2.2. Buffer Creation and Data Types. { CHKBB , L<>H , L-H , H=L }

- **CHKBB** – Check (and create) Buffer.

  Seminal routine accessed by *every* single one of the module functions: use it to create the 16C Data buffer when needed – as it is done automatically during the CALC_ON event (polling point).

- **L<>H** – Swap Lower and Higher bits.

  You can use this function to swap the low and high bits parts of the 16X register. In other words, the contents of the stack- X and buffer b13 registers will be exchanged, doing the required conversions as appropriate: b13 = BIN(X), and X = BCD(b13).

  Example: using a word size of 56, enter the hex value 12300000000000

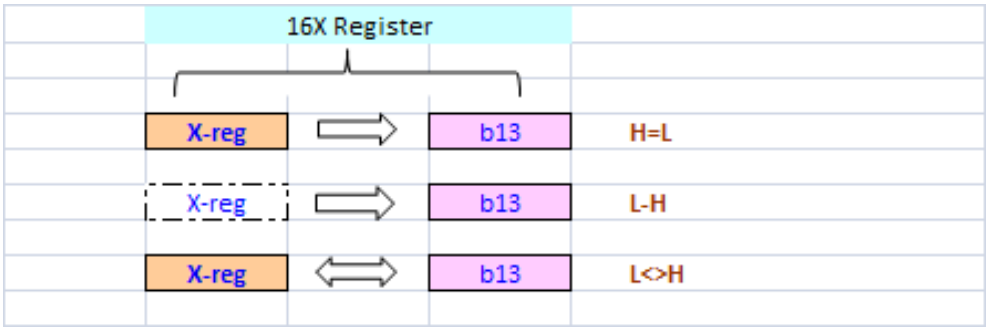
  Type: **16NPT**, "123", **L<>H** => H:12300000000000
  If you execute it again you'll get the original "123" input, i.e. the digits will be shifted down.

- **H=L** and **L-H** – Copy and Move Lower bits

  These two complement the swapping functionality, and provide ways to copy and move the lower bits art of the 16X register into the higher bits. In both cases the previous content of b13 will be overwritten, and in the move case (L-H) the X register will be cleared after the copy.

  A pre-requisite for these functions is that the current word size needs to to be larger than 32 in order for the higher bits register to be shown during the masking process. If this is not the case the rerror message "WS=nn" will be shown (or "DATA ERROR" in a program execution).

  The schematic below graphically shows the actions performed by these three functions:



4.2.3. Doubling and Halving the 16X value. { 2MLT , 2DIV }

- **2DIV** and **2MLT**

  Handy shortcuts to divide or multiply the contents of the 16X register by two. It saves bytes in a program and keystrokes during manual mode. It does not lift the 16C stack but saves the original number in LST16X. Note however that the CY and OOR flags are not always set by these functions.

4.2.4. Digit Justification, Reversal and Decimal Sum. { DGLJ , DGRV , DGDΣ }

These functions can be considered an extension of the bit-based conterparts, **LJY**, **REV**, and **#BITS**. The concepts are analogous to the original set, but these are digit-based instead of bit-based. The results may be sometimes similar or even the same, but in general thay are totally different.

- **DGLJ** does a digit-based left justification of the value in 16X, which in general is not the same as the bit-based function **LJY** available in the main FAT (and in the original 16C). Only when the bit density of the leftmost character (i.e. the number of bits per character) is complete then both functions will yield the same result.

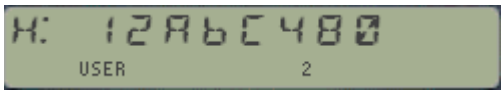
Example: with ws=32, left-justify the value H: 123 using bits and digits as criteria:

, vs:


- **DGRV** does a full-digit reversal (i.e. mirror image) based on the information contained in the ALPHA register. This should normally be based on the actual value in 16X, and therefore it'll return a digit-reversed version of the number. The result will be normalized to fit within the current ws and complement mode selected. The original value is saved in 16L, the last-16C register.

  Note that contrary to the bit-reversal situation, the result here is completely base-dependent. Also note that Zero chars on the left (after reversion) will ultimately be ignored. Obviously this function is completely equivalent to **REV** for binary mode, since in that case each bit corresponds to one digit as well.

Examples: with ws=32, any complement mode:



DGRV


but say now you have ws=8

DGRV


- **DGDΣ** does a decimal digit sum based on the bcd values from 16X – independently from the base mode set. The decimal result is briefly shown as a flashing message in the display, and then it is input in the 16X level (in the configured based) replacing the original value – which goes to the 16L register as well.

, then:


(Note: remember that the sigma character in a sub-function name cannot be directly entered via the "Σ" key (SHIFT-F) in ALPHA mode; thus you need to use the 'N" character i.e. for "**^NDGT**" instead.)

4.2.5. Test for Maximum Negative (signed) Value. { MNV? }

- **MNV?** is a test function to check whether the number in 16X is the Maximum Negative signed Value (MNV) for the currently selected word size. The result will be YES/NO, skipping a program line if false – as with any standard tests.

Of all the conventions used on the 16C calculator one of the trickiest to grasp is that of the maximum negative value for signed complements. Even if the definition is clear enough, some of the particular function results when the operand is such a maximum negative value may be unexpected or even disconcerting to the untrained eye – and it accounts for many numerous singularities in the general algorithms to properly emulate the real machine.

For starters, this is the only value that equals its own **16CHS** in 2CMP – This is not the only remarkable thing about it, but remember this one, we'll use it later on.

We define the maximum negative value as the largest absolute number with a negative sign - i.e. the msb is set in either 1CMP or 2CMP. Given the arrangment of the negative values (see appendix 1B) the maximum negative happens to be that such all other bits are zero, and therefore can easily be generated calling **LJY** on the number "1"; or creating a single bit **MSKL** ; or also doing a left-shifting of (ws-1) number of bits with **SLN**.

Corner cases involving the MNV.

Setting ws=32, 2CMP, let's do some math using the MNV(32) = H: 80000000 as one of the arguments. (i.e. d: -2147483648)

Multiplying or dividing the MNV by -1 is perhaps an academic discussion but calculating the result poses some challenges to the algorithms. The 16C responds the following in 2CMP:

Division: **16NPT**, "1", **LJY**, **16NPT** "0", **NOT**, **16/** => H: 0, and OOR
Multiplication: **16NPT**, "1", **LJY**, **16NPT** "0", **NOT**, **16*** => H: 0, and OOR

Note that the last one yields a *different result from a sign change of the MNV*, i.e. both operations are surprisingly not equivalent in this case.

Is that a picky behavior or is it justified? Mathematically speaking multiplying by -1 should be equivalent to doing **16CHS**, and for the MVN that results in the same MVN – not zero/OOR. But this is not how it works here, where the rule for a sign change is "invert, then add one", and not a multiplication by -1 . Such is life in the digital world!

To Get	in Mode	Argument	w/ Operation	and Arg.#2	w/ Op#2
-1	2CMP only	0	NOT		
-1	1CMP only	0	NOT	1	16-
-1	Signed modes	1	16CHS		
-0	1CMP only	0	NOT/16CHS		
MNV	Signed modes	1	LJY		
MNV	Signed modes	ws-1	MASKL		
MaxVal	Unsigned Mode	0	NOT		
MaxVal	Signed modes	1	LJY	result	16CHS

In 1CMP: 0 – 1 = -1 /CY; adding 1 again returns -0 instead of the original 0.

4.2.6. Quick Dec <-> Hex conversions. { D>H , H>D }

These two functions perform a quick & dirty conversion between decimal and (unsigned) hex values using the real X-register and ALPHA. Use then when you want to check results independently from the selected base on the emulator.

The maximum number allowed is H: 2540BE3FF or d: 9,999,999,999 in decimal. Both functions are mutually reversed, and **H>D** does (real) stack lift as well.

These functions were written by William Graham and published in PPCJ V12N6 p19, enhancing in turn the initial versions first published by Derek Amos in PPCCJ V12N1 p3.

4.2.7. Recalling the current base value. { BASE? }

- The function **BASE?** recalls the value of the current base to the 16X register – as an easy way to find it out in a running program. The value is pushed into the 16C stack. Possible return values (in decimal) are 2, 8, 10, and 16 – always shown as "10" in their digital display.

This function is similar to **16WSZ?** in that both return configuration data to 16X, and that in manual mode an information message will also be displayed:

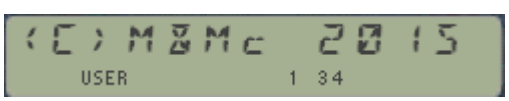
4.2.8. Alpha Reverse and Left append character. { X-LA , AREV }

- The function **X-AL** appends the character which ASCII code is in X to the left side of the ALPHA string. It is therefore the symmetrical of **XTOA**. This function was written by Håkan Thörngren, and first published in PPCJ V13 N7 p9. It is used as a subroutine by the Leading Zeros functionality, within the function **LDZER**.

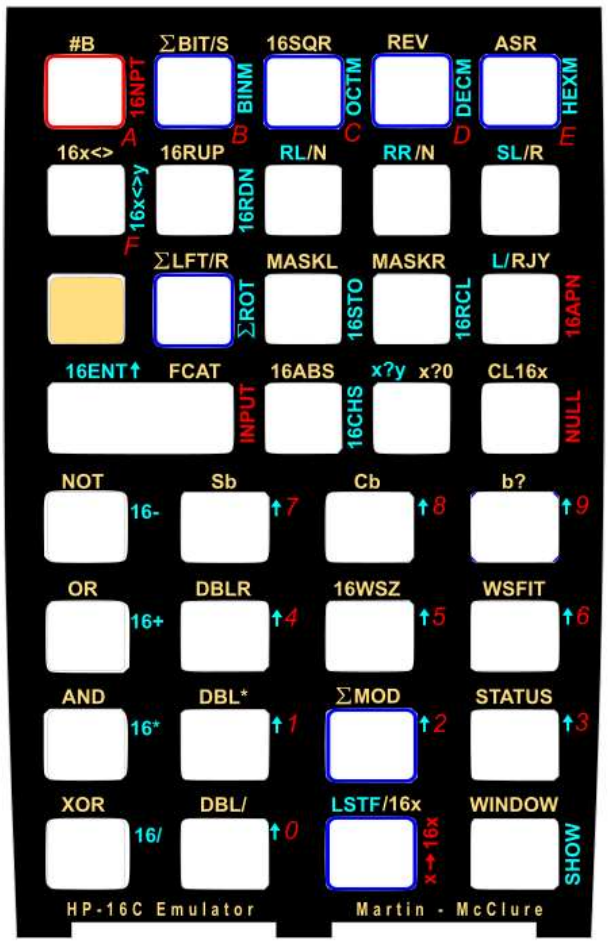
- The function **AREV** does a mirror-image of the ALPHA register contents. It was written by Frans de Vries and first published in DF V10 N8 p8. It is used as an internal subroutine by the Digit Reversal, within the function **DGRV**.

Copyright Message "Easter Egg" { (c) }

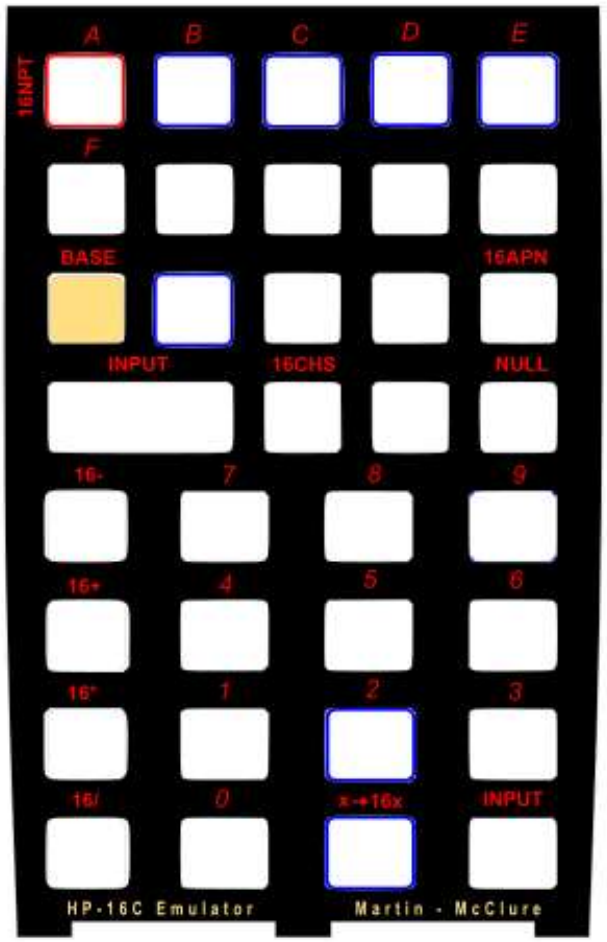
So you can amuse your friends, a copyright message with a fancy sound can be invoked using the **(c)** function, with index# =060 in **16#** - to access this message:



5.- APPENDICES



HP-16C Emulator



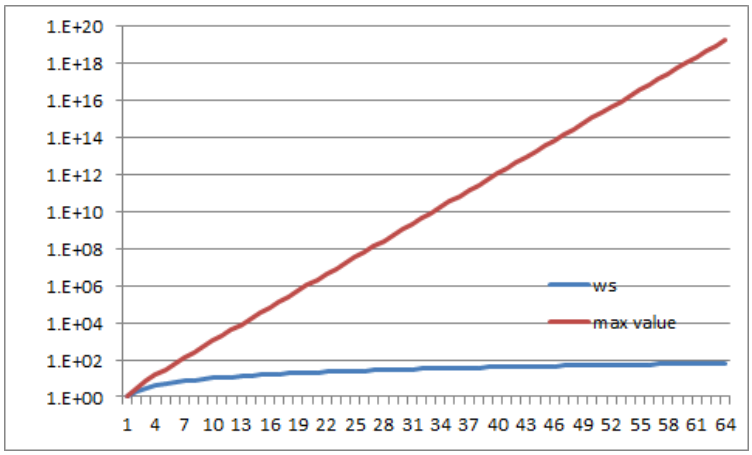
16NPT Hot keys

Appendix A1. Maximum Values depending on the Word Size.

The table below shows the maximum possible values that can be represented as a function of the selected word size. These values are also returned by the function **WSMAX** for the current selection of ws (in floating point format, native to the 41C OS).

ws	max value	ws	max value
1	1	33	8,589,934,591
2	3	34	17,179,869,183
3	7	35	34,359,738,367
4	15	36	68,719,476,735
5	31	37	137,438,953,471
6	63	38	274,877,906,943
7	127	39	549,755,813,887
8	255	40	1,099,511,627,775
9	511	41	2,199,023,255,551
10	1,023	42	4,398,046,511,103
11	2,047	43	8,796,093,022,207
12	4,095	44	17,592,186,044,415
13	8,191	45	35,184,372,088,831
14	16,383	46	70,368,744,177,663
15	32,767	47	140,737,488,355,327
16	65,535	48	281,474,976,710,655
17	131,071	49	562,949,953,421,311
18	262,143	50	1,125,899,906,842,620
19	524,287	51	2,251,799,813,685,250
20	1,048,575	52	4,503,599,627,370,490
21	2,097,151	53	9,007,199,254,740,990
22	4,194,303	54	18,014,398,509,481,983
23	8,388,607	55	36,028,797,018,963,967
24	16,777,215	56	72,057,594,037,927,935
25	33,554,431	57	144,115,188,075,855,871
26	67,108,863	58	288,230,376,151,711,743
27	134,217,727	59	576,460,752,303,423,487
28	268,435,455	60	1,152,921,504,606,846,975
29	536,870,911	61	2,305,843,009,213,693,951
30	1,073,741,823	62	4,611,686,018,427,387,903
31	2,147,483,647	63	9,223,372,036,854,775,807
32	4,294,967,295	64	18,446,744,073,709,551,615

Also shown in the graphic below using a logarithm scale:



Appendix A2. The Hexadecimal Number System

The base of this number system is 16(d). The numbers 0-9 as well as the letters A to F are used to represent 11(d) to 15(d). The carry over to the next place occurs at 16(d). The table below shows the correspondence between binary, decimal and hexadecimal numbers up to 15(d):

Hex	Binary	Decimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
A	1010	10
B	1011	11
C	1100	12
D	1101	13
E	1110	14
F	1111	15

As you can see on the table, Hex numbers are the natural choice to represent four binary digits (4 bits); therefore the hexadecimal number system uses the 4 bits of a nibble in the full value range. Each nibble can represent values from bin 0000 to 1111, of in hex from 0 to F. This number system is often used in computer science.

Representation of negative Numbers

When using a limited count of digits m to represent numbers, the value range to the numbers to be represented n is $0 < n < 2^m$, meaning that the greatest number will be $2^m - 1$. Note that no negative numbers are included in this system of notation. To remove this deficiency, the concept of "complement" is introduced.

The Complement (from a reference K)

The K-complement of a number x is defined as the difference from K of that number: Com(x) = K–x for which k is fixed by the chosen complement. Since in the binary number system the usual values of K are 2^m, and $(2^m - 1)$, we usually speak of "one's complement" or the "two's complement" – representing the difference from either the greatest number represented or the one after it. In general, for any base system "b" there will be a "b" and a "b-1" complement – like the 9's and 10's complement in the decimal system where b=10.

Distribution of ranges of values.

If there seems no reason yet for the existence of complement notation, remember that to this point we haven't dealt with negative numbers. We shall include these by adopting an arbitrary distribution of value ranges in our number systems. For instance in the binary system, we'll define a negative number as one which most significant (leftmost) bit is set (has a value of 1). Arranging number distributions and using complements change the ranges of values as follows:

No Complement	$0 < x <= (b^m - 1)$
b-Complement	$-b^{(m-1)} <= x <= b^{(m-1)} - 1$
(b-1) Complement	$-b^{(m-1)} - 1 <= x <= b^{(m-1)} - 1$

Basically in the signed modes (with complement) we divide the original total value range b^m-1 in two half sections, allocating one of them for negative numbers and the left over for positive.

Complement (Signed) Modes.

The transformation of decimal numbers represented in the binary system (and vice-versa) varies with the signed mode used. The three modes are:

- Unsigned mode (no complement, only positive numbers)
- 1's complement mode
- 2's complement mode

The 1's Complement of a number is calculated by subtracting this number from the greatest representable number in the chosen word size (number of bits). For instance, say the word size is 5 bits – then the 1's complement of a number "a" is (11111 – a). The computer simply inverts all bits of the original number, i.e. executes the logical function "NOT". Through this segmentation of the initial value range (arbitrary but specific), all negative numbers have their highmost bit set, which plays the role of the minus sign. In the q's complement mode the number of positive and negative numbers represented are the same, i.e. even zero has two possible representations: +0 and –0, which in binary would be 00000 and 11111 (always assuming a word size of 5 bits).

The 2's Complement of a number is calculated by adding one to its 1's Complement. Using the same example of word size 5 bits, the 2's Complement of a number "a" would be (11111 – a) + 1, The 2's complement of bin 10001 is the number bin 01111. Notice how also in this segmentation the leftmost bit is set for all negative numbers, and therefore takes over the role of the minus sign. In the 2's complement mode there is one more negative number than in the positive number range, since zero only has the representation +0

The Unsigned Mode (no complement). Since the Complement mode employs one bit as the negative sign, the range of values for a word size of 8 bits in the 1's complement is from –127 (d) to +127(d), and in the 2's complement from –128(d) to +127(d). Note that in both cases those are 256 values. For cases when only the positive number range is needed, the precedence sign bit is not necessary (unsigned mode) and the value range is used for all cases from 0 to 255(d) - assuming the same word size of 8 bits.

In the table below you can see the correspondence between the three sign modes for decimal numbers 0-15 represented in binary, using a four-bit word size:

Dec	Hex	Binary	Unsigned	1's Compl.	2's Compl.
0	0	0000	0	0	0
1	1	0001	1	1	1
2	2	0010	2	2	2
3	3	0011	3	3	3
4	4	0100	4	4	4
5	5	0101	5	5	5
6	6	0110	6	6	6
7	7	0111	7	7	7
8	8	1000	8	-7	-8
9	9	1001	9	-6	-7
10	A	1010	10	-5	-6
11	B	1011	11	-4	-5
12	C	1100	12	-3	-4
13	D	1101	13	-2	-3
14	E	1110	14	-1	-2
15	F	1111	15	-0	-1

Appendix B1.- Programming Examples.

Let's see an example of how the 16C Emulator module functions are used in a program. We'll use the Checksum Calculation example from the 16C manual, pages 90, 91 and 92.

The program assumes you have pre-loaded 4-bit hex values in registers R1 to R10, as follows:

R01: A	R03: B	R05: 3	R07: A	R09: D
R02: 7	R04: 1	R06: D	R08: 2	R10: 6

The table below shows both the original program and the equivalent using the Emulator functions for a side-to-side comparison; not surprisingly very similar in concept but with some differences – especially in the 16C stack management.

hp-16c Program		16C Emulator Code	
1	**LBL D**	1	**LBL "CHKS"**
2	**UNSIGN**	2	**UCMP**
3	**4**	3	**4**
4	**WSIZE**	4	**16WSZ**
5	**HEX**	5	**HEXM**
6	**"A"**	6	**10**
7	**STO I**	7	**STO 00**
8	**0**	8	**CLX16**
9	**ENTER^**	9	**16ENT^**
10	**LBL 0**	10	**LBL 00**
11	**RCL (I)**	11	**16RCL**
12	**B#**	12	**128**
13	**+**	13	**#BITS**
14	**X<>Y**	14	**16+**
15	**0**	15	**16X<>Y**
16	**RLC**	16	**0**
17	**+**	17	**16LOW^**
18	**X<>Y**	18	**RLC**
19	**DSZ**	19	**16+**
20	**GTO 0**	20	**16X<>Y**
21	**RTN**	21	**DSZ**
		22	**GTO 00**
		23	**SHOW**
		24	**END**

Remarks:

1. Indirect Register "I" corresponds to R00
2. RCL (i) uses the indirect capability of **16RCL**, adding 128 to the 16C-register number.
3. Note the non-merged arrangement in lines 11 & 12 for **16RCL**, with the rg# in the next program line.
4. Note how the parameter for the word size is in the 16X register – lines 3 & 4. In fact here we use an insider's trick using just the real-X register (only valid for 16WSZE!)
5. Sub-functions (in brown color) really use the **16C#** launcher followed by an index number
6. Entering 16C values requires either 16NPT or **LOW16^** for numbers below 32 bits. This is how zero was input in lines 16 and 17.
7. **DSZ** operates on standard values – as an index very much like ISG and DSE do.
8. A final **SHOW** instruction has been added to see the 16C result.

Note how all the stack lift and drop are performed in exactly the same way as in the original machine – pretty much following the same rules as in all RPN designs.

Appendix B2.- Square Root using Newton's Method

The program below is an alternate (and very slow!) way to calculate the square root of a number, simply using an iterative approach following Newton's method:

Finding $\sqrt{S}$ is the same as solving the equation: $f(x) = x^2 - S = 0$

Therefore, any general numerical root-finding algorithm can be used. Newton's method, for example, reduces in this case to the so-called Babylonian method:

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)} = x_n - \frac{x_n^2 - S}{2x_n} = \frac{1}{2}\left(x_n + \frac{S}{x_n}\right)$$

The program uses the initial estimation: x0 = 6 * log(S)

Data registers R01 and R02 are used to store the successive approximations, Xn.

1	LBL "64SQRT
2	CF 21
3	16X^^^
4	LOG
5	6
6	*
7	LOW^16
8	16STO
9	LBL 00
10	16RUP
11	16X^^^
12	16RCL
13	16/
14	LST16X
15	16+
16	2
17	LOW16^
18	16/
19	16ENT^
20	16X<>
21	16X<>Y
22	16X#Y?
23	GTO 00
24	SHOW
25	END

Example: Calculate the square root of ABC,DEF,ABC,DEF

16NPT, ABCDEFABCDEF, => H: ABCDEFABCDEF
XEQ "64SQRT" => H: D1B7FD

Appendix B3.- Showing leading zeros – A FOCAL reprise.

The program below is a parallel version of the MCODE function available in the module – it basically uses the same method so you can see how it's been implemented; in particular is a good example of the **BASE?** function.

1	LBL "LEAD"		29	ABSP	remove base id#
2	16STO (00)	Ssave value	30	ABSP	
3	WSZE?	get word size	31	ABSP	
4	STO 00	put in R00	32	RDN	#chars
5	0		33	ALENG	ALPHA length
6	X<>F	reset flags	34	STO 00	save for later
7	BASE?	{2, 8, 10, 16}	35	-	# of zeros
8	LN		36	LBL 00	
9	2		37	"|-0"	add one
10	LN		38	DSE X	decrease counter
11	/	#bits/char	39	GTO 00	do next
12	FIX 8		40	RCL 00	ALPHA length
13	RND	rounded	41	AROT	rotate ALPHA
14	SF IND X	flag case	42	FS? 04	Hex?
15	FRC	remainder	43	"|-H"	yes,
16	X#0?	was it decimal?	44	FS? 03	Oct?
17	GTO 05	yes, do nothing	45	"|-O"	yes,
18	RCL 00	ws	46	FS? 01	Bin?
19	LASTX	#bits/char	47	"|-b"	yes,
20	/	#chars	48	"|-: "	append blank
21	ENTER^		49	-3	rotate contents
22	INT	make integer	50	AROT	
23	X#Y?	was it round?	51	AVIEW	show result
24	ISG Y	no, add one	52	16RCL (00)	recall argument
25	NOP		53	RTN	done.
26	RDN	#chars	54	LBL 05	Decimal
27	3		55	16RCL (00)	recall argument
28	AROT	rotate ALPHA	56	SHOW	show current
			57	END	

As you can see all action happens in the ALPHA register – and therefore the usage of the standard X-Functions **AROT**, **ALENG** – and **ABSP** from the OS/X module as well. Not only this program requires the data registers 16R00 to preserve the original value, but it should also be said it will fail in 1/2CMP due to the incompatible usage of user flags 1 and 2.

Appendix C.- Data Buffer Technical Details.

This document is an attempt to descript the format of the B buffer used by the HP-16 MCODE Emulator Module developed by Angel Martin and Greg McClure. The B buffer is used to allow full 64-bit word size emulation (as implemented on the HP-16).

The buffer requires 20 free registers. Function CHKBB (check for buffer B) is used to check for, and create if needed, buffer B. The format of the buffer (from highest absolute register to lowest absolute register) is shown below, and individual sections will be discussed after.

```
F7 0bbbbbbbb 00l   Input / Output sub-buffers, the "Windows" of the
F6 0bbbbbbbb 00l   HP-16.  It is used for input of digits (for bin,
F5 0bbbbbbbb 00l   oct, dec, and hex modes) by user, and for output
F4 0bbbbbbbb 00l   of results of function or view.
F3 0bbbbbbbb 00l   In bin mode, b=0 or 1; oct mode, 0<=b<=7;
F2 0bbbbbbbb 00l   dec mode, 0<=b<=9; hex mode, any hex digit.
F1 0bbbbbbbb 00l   These digits are store in reverse of display or input.
F0 0bbbbbbbb n0l   b=bcd digit, l=number of digits used, n=negative
E3 0aaaaaaaa 000   Temporary calculation registers.  E0 and E1 are used
E2 0aaaaaaaa 000   several purposes, E2 and E3 are for double precision
E1 0aaaaaaaa 000   functions DBL* and DBL/.
E0 0aaaaaaaa 000
14 0lllllllll 000  These are the upper 32 bits for the stack registers.
13 0xxxxxxxx 000   The HP-41 can only save 32 bits of info in its std
12 0yyyyyyyy 000   stack, these hold the other 32 bits of simulated regs.
11 0zzzzzzzz 000
10 0ttttttttt 000
01 0mmmmmmmm 0cd   m represents the mask based on word size. Wordsize is
00 0mmmmmmmm 0bb   stored in bb, c is complement's mode, d is calc mode.
BB 14f000000 xxx   Header with buffer id#, buffer size, and loud mode flag.
```

BB buffer register (Header)

Let's start with the BB buffer header. It is required to identify the buffer, and the HP-16 MCODE Emulation module will refresh this header on power on (as all buffers are refreshed by the individual modules that require their use). The 14 is the buffer size in hex (requires 20 registers). The "f" is the Silent/Loud mode flag used for message displaying. Nothing more is stored in this header. (Note that the S&X field is used by function **BFCAT** and therefore is reserved).

Buffer registers 00 and 01

The 00 and 01 register hold a calculated mask that will help in making decisions (carry status, out-of-bounds conditions, etc) on the status of arithmetic and logic functions. It is related to the word size (bb) and is described below:

For word size <= 32: All 01 m fields will be 0, i.e. it will contain 01 000000000 0cd. The 00 m fields will represent the bits allowed in values to be saved and used. Some examples are: 00 0FFFFFFFF 020 (for 32 bits), 00 00000FFFF 010 (for 16 bits), etc.

For word size > 32: All 00 m fields will be F, i.e. it will contain 00 0FFFFFFFF 0bb. The 01 m fields will represent the upper bits allowed in values to be saved and used. Some examples are: 01 0FFFFFFFF 0cd (for 64 bits, where bb would be 40), 01 00000FFFF 0cd (for 48 bits, where bb would be 30).

The cd bits in buffer register 01 show the current complements mode, c, and binary mode, d. If c=0, no complement mode is set, c=1 means 1's complement is set, c=2 means 2's complement is set. These settings influence both display and calculation flag results. If d=0, floating point mode is set, and the HP41 registers act as normal (no emulation is in effect). If d=1 then bin mode is in effect, d=2 means oct mode, d=3 means dec mode, and d=4 means hex mode.

Buffer registers 10 thru 14

When bin, oct, dec, or oct mode is in effect and word size > 32, then these buffer registers contain the upper bits (beyond the 32 stored in the standard stack). For example, if the HP-16 "X" register should contain the hex value 1234 5678 9ABC DEF0, then buffer 13 will contain 13 012345678 000 and actual HP41 register X will contain the floating point value corresponding to 9ABCDEF0, that is, 2,596,069,104. This is done to insure the registers can always been viewed in floating (not have weird Non-Normalized contents). The same pairing of a buffer register and a stack register exists for each of the stack registers, thus emulating the HP-16 64-bit binary stack. The pairing is as follows:

Buffer register	+ HP41 stack register	= HP-16 emulated register
b10	Binary(T)	16T
b11	Binary(Z)	16Z
b12	Binary(Y)	16Y
b13	Binary(X)	16X
b14	Binary(L)	16L

Buffer registers E0 thru E3

These buffer registers are ***scratch registers***. They are used for holding partial results, for holding the dividend when translating binary output to digital representation, and for construction of binary values on user input. Their purpose changes based on the function being simulated. The masks of buffers 00 and 01 are applied here to insure values are in range, and to determine the proper carry and out-of-range flag settings. An example of their use for digit input and display output is show in the discussion of the F0 thru F7 buffer registers. *They can't be counted on to hold any values of use between functions, and can be overwritten by any function needing them.*

Buffer registers F0 thru F7

These buffer registers hold the digit representations of the binary values input from the keyboard, or the digit representations of the binary values to output to the display. Similar to the Q register on entry of some kinds of alpha data, binary values are written in or read out in reverse order. For the multiplication and division routines, some of these buffer registers are also used as scratch registers.

The input routine takes digits entered by the user and stuffs them into these registers from right to left, starting at F0 and continuing to F7. The number of digits entered in a particular register is placed as the rightmost digit of the buffer, and up to eight digits can be entered into positions 3 thru 10 of each register. This allows up to 64 digits (max possible for binary value with max word size) to be entered. As an example: in oct mode 1234 1234 5656 is entered by keyboard. The contents of buffer registers F0 and F1 will contain:

```
F1 000006565 004
F0 043214321 n08
```

Notice that the digits are entered from right to left, starting at position 3 of each register until finished. All other Fx buffer registers will contain 0 length and 0 bcd values. The negative indicator would be 0, since octal values do not include a sign.

After input is completed, the bcd to bin translation routine would then create the binary representation of this octal number and place these into the following Ex buffer registers:

```
E1 000000002 000
E0 09C29CDAE 000
```

representing binary 2 9C29 CDAE (in hex). The X register would receive decimal value of 9C29CDAE(hex) and buffer register 13 would receive the 2 (assuming word size >= 34).

The output routine will take a value placed in the EX buffer registers and translate them to digits in the Fx buffer registers. Then control will be given to the display routines which will use these registers as HP-16 Windows. For example, assume the binary value in E0/E1 buffer registers are:

```
E1 000000222 000
E0 033334444 000
```

The bin to bcd translation routine would then take these values and translate them to the Fx buffer registers based on mode (bin, oct, dec, hex). It will first clear all Fx buffer registers, then for oct mode, the following will be placed into the Fx buffer registers specified:

```
F1 000360124 006
F0 040121341 n08
```

which represents 42 1063 1431 2104 octal. Window 1 on HP-16 would hold 421063 and Window 0 would hold 14312104. Notice these values are read from right to left. Again, since this is octal, n is 0 to represent no sign.

Negative value flag for Decimal signed modes

The XS digit of the F0 register has a special function to denote that a negative value is to be presented in the LCD when a signed decimal base mode is the selected one. When the value is not zero it will direct the [SHOW] routine to add a minus sign before the value, for the familiar representation convention. This is also controlled by the complement mode, and built in the [EX2FX] code.

Functions buffer usage outlines

The following sections will show how the buffers are used in various math / logic / programming functions. One of the first things that will be noticed is that in addition to the auxiliary E2 and E3 buffer registers, for more complex cases buffers F0 and F1 are here also used as temporary registers for calculation purposes.

Input/Output Routines

Input of various values for calculation is accomplished via several possible routines mentioned in this manual (**16NPT**, **LOW16^**, **16APN**). At the core of these functions are the [FX2EX] and [EX2FX] routines (which are also available as sub-functions) that move the results of input back and forth between the FX registers and buffers E0 thru E2. The info in buffers F0 thru F7 are ASCII values.

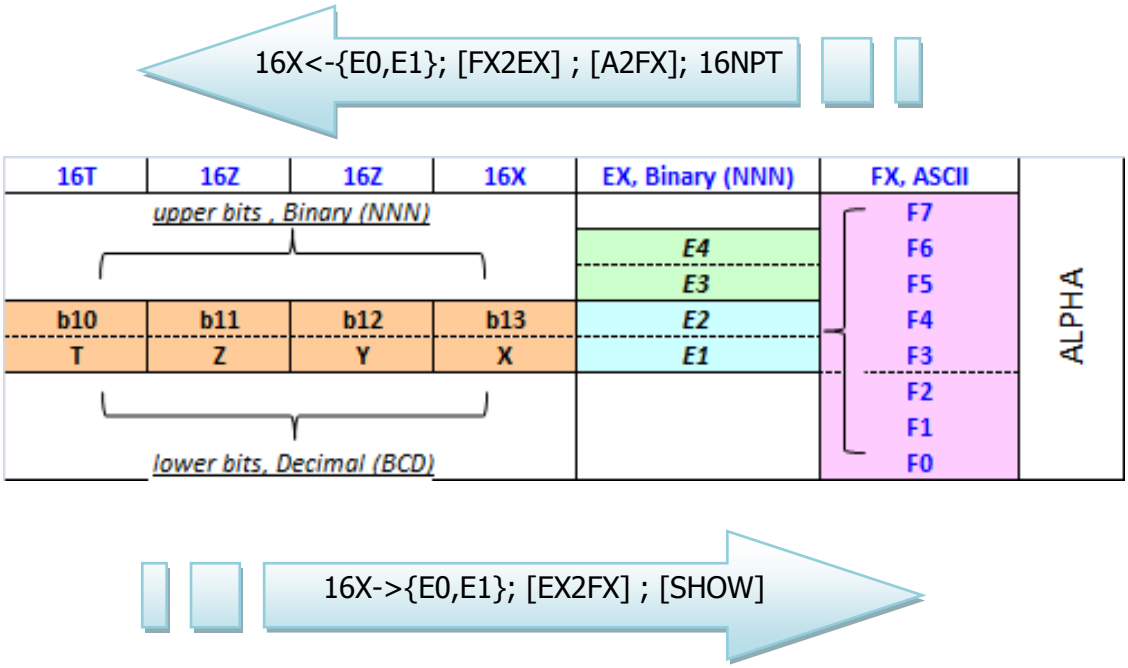
The **FX2EX** function translates the ASCII codes in buffers F0 thru F7 into binary in buffers E0 and E1. It relies on the mode set in buffer register b01 (BIN, OCT, DEC, HEX). For BIN, OCT, and HEX modes this is easy. It takes the info from each ASCII code in the F0 thru F7 buffers and shifting it into buffer E0 (overflow bumping into buffer E1). In decimal, a special multiply by 10 and add value routine is required to perform the translation into binary (instead of shifting by 1 [BIN], 3 [OCT], or 4 [HEX]).

Every math or logic routine will use the info in buffers E1/E0 as the 16X argument. The result that should be in the 16X argument at the end of the routine is placed into buffers E1/E0, and a routine is called to move that into the 16X register and displayed. The internal routine E01OUT is used to do this. The **EX2FX** routine is at the core of this process. The display functionality of E01OUT is reproduced with the **SHOW** function.

EX2FX is the mirror of the **FX2EX** routine. It takes the info in E0 and E1 and translates it into buffers F0 thru F7. Again it relies on the mode set in buffer 01 (BIN, OCT, DEC, HEX). For BIN, OCT, and HEX modes this is straightforward, bits are shifted into the buffers and changed into ASCII codes. For DEC mode, a special routine to divide by 10 also has to be implemented. The sign of the decimal value has to be considered as well (it is the only mode we have to worry about the sign). As digits are found, the contents of buffer F0 thru F7 are shifted, and a proper count is maintained for each buffer. Buffer register F0 also contains the negative indicator if DEC mode and the value represents a negative value (only occurs in 1's or 2's complement mode).

Similar to the previous one, there is also a sub function available to execute the internal routine for diagnostic cases. It will assume the information is already in binary format in the EX registers to move it up to the FX registers in ASCII form.

The hierarchical levels amongst the input registers are shown again in the figure below, with the sequence of routines needed to move the data up and down the different stages:



Multiplication routine

The multiplication routine covers both **16*** and **DBL*** in one routine. When the code needs to be specific, it uses an internal system flag (specifically system flag 5) to perform the unique code for the specific function. The beginning of the routine is basically the same:

1) 16LastX is performed to save the value of buffer 13 and stack register X into buffer 14 and stack register L. The binary value of Y and contents of buffer 12 (16* multiplier) are moved to buffers E2 and E3. The binary value of X and buffer 13 (multiplicand) are already in E0 and E1.

2) If in 1's complement or 2's complement mode, take the absolute value of both the multiplicand and the multiplier, saving the state of the combined signs in one of the CPU internal registers (G in case you're curious).

3) The high order of the absolute values of the multiplicand and multiplier are saved back to buffers 13 and 12, the low order bits are saved to buffers F0 and F1 respectively. Thus multiplicand is now in buffers 13/F0, multiplier is now in buffers 12/F1.

4) Now a full cross multiply is performed (using 16 bits at a time, thus 16 total cross multiplications) into buffers E0 (low order) thru E3 (high order); this is the core part of the multiplication routine. This routine is explained later in this section.

5) Notwithstanding a lot of weird code that checks for overflow or carry flag conditions, the routine then divides into single precision (16*) and double precision (DBL*) result sections. Here are the two possible paths:

   a) For SINGLE PRECISION, the result may need a sign change (1's complement or 2's complement mode); then an extended stack drop is performed (including buffers 10 thru 12 dropping down to buffers 11 thru 13) and the contents of the result in buffers E1 and the BCD expansion of E0 are placed into buffer 13 and stack register X respectively

   b) For DOUBLE PRECISION, three steps are required:

      1) The result needs to be shifted so that the proper bits are separated into E3/E2 for high order and E1/E0 for low order (based on word size); both buffer register pairs need to contain values within the word size required.

      2) The routine first checks to see if it may need a sign change (1's complement or 2's complement mode); this check changes the order of the result to buffer order E1/E0/E3/E2 (from high order to low order).

      3) The result in buffers E3 and the BCD expansion of E2 (low order) are placed into buffer 12 and stack register Y respectively (since that is where the low order piece is stored for DBL*) and buffers E1 and the BCD expansion of E0 (high order) are placed into buffer 13 and stack register X respectively.

6) The multiplication routine returns via a routine that translates the values in buffers E0/E1 into buffers F0 thru F7, and displays the result.

Some of the seemingly redundant moves of values are explained by the fact that the change sign routine (described later) works on data in buffers E1 and E0. Routines exist for easy exchange of buffers E1 and E0 with E3 and E2, and for taking buffer 13 and the binary of stack X and putting it back into buffers E1 and E0. Taking advantage of these routines dictated these moves. Also note that for DBL* no stack drop is required at the end, since the multiplicand and multiplier are replaced with the double precision result.

The cross multiplication step is carried out by taking the multiplicand and multiplier and separating them into 16 bit chunks. This is required because there is no multiply instruction for the internal chip of the 41C. The actual multiply workhorse routine takes a 16 bit multiplier and 16 bit multiplier and yields a 32 bit result. This result is then moved or summed into the required locations in buffers E0 thru E3. The multiplicand saved in buffers F0/13 and multiplier saved in buffers F1/12 can be represented as hex digit groups as follows:

F0: aaaa bbbb	13: cccc dddd
F1: eeee ffff	12: gggg hhhh

The 16 cross multiplications are:

1) dddd x hhhh into buffer E0 (moved)

2) cccc x hhhh + dddd x gggg into low 16 bits of buffer E1 (moved) and high 16 bits of buffer E0 (summed)

3) bbbb x hhhh + cccc x gggg + dddd x ffff into buffer E1 (summed)

4) aaaa x hhhh + bbbb x gggg + cccc x ffff + dddd x eeee into low 16 bits of buffer E2 (moved) and high 16 bits of buffer E1 (summed)

5) aaaa x gggg + bbbb x ffff + cccc x eeee into buffer E2 (summed)

6) aaaa x ffff + bbbb x eeee into low 16 bits of buffer E3 (moved) and high 16 bits of buffer E2 (summed)

7) and finally aaaa x eeee into buffer E3 (summed)

Thus 16 total cross multiplications are performed. The last section of the multiply core normalizes buffers E0 thru E3 (handles carries from E0 to E1, E1 to E2, etc). Thus, when double multiply is performed with the max word size of 64 bits, a full 128 bit result can be calculated.

Change Sign Routine

An important part of both the multiplication and division routines when working in 1's complement or 2's complement mode is the subroutine [CHSUB], also used in function **16CHS**. It basically takes the value in buffer E1/E0 and performs a 1's complement or 2's complement on it. Buffer E1 is then copied to buffer 13 and the BCD of E0 is copied to stack register X.

Such a seemingly simple task has however its quirks as a result of the definition of a value's complement. The maximum negative signed value in particular is an interesting boundary that needed to be single-cased for this routine to work correctly in 2CMP mode.

Division routine

The division routine actually covers **16/**, **RMD**, **DBL/**, and **DBLR** in one routine. Whether a divisor or remainder is required, division must still be performed. When the code needs to be specific, it uses two internal system flags (specifically system flags 0 and 5) to perform the unique code for the specific function.

Since there is no division instruction for the internal chip of the 41C, it was necessary to figure out how to do division of values bigger than the max size of the 41C registers. This was accomplished by the method of partial division. The core routine used takes a dividend and divisor up to 40 bits, and the result yields both a quotient and remainder.

Partial division takes progressive high order pieces of the dividend and a shortened divisor (usually 20 to 24 bits) and uses the core routine to yield a partial quotient. The full divisor is multiplied by the partial quotient and subtracted from the dividend. Occasionally this results in a negative value of the remaining dividend, so the partial quotient is adjusted to allow a positive difference. The final dividend after subtraction is used for the next partial division.

The length of the partial divisor and piece of dividend depends on the length of the full divisor. For divisors less than up to 24 bits the full divisor is used and no multiply and subtraction adjustment is required.

Here is the division process in detail. In actual code, the process is divided into multiple sections based on divisor length, and whether single or double dividend length.

1) 16LastX is performed to save the value of buffer 13 and stack register X into buffer 14 and stack register L.

2) For 16/ and RMD, the binary value of Y and contents of buffer 12 (dividend) are moved to buffers E2 and E3. The binary value of X and buffer 13 (divisor) are already in E0 and E1.

3) For DBL/ and DBLR, the binary value of Y and contents of buffer 12 (high order dividend) are moved to buffers F0 and F1. The binary value of Z and contents of buffer 11 (low order dividend) are moved to buffers E2 and E3. The binary value of X and buffer 13 (divisor) are already in E0 and E1.

4) For DBL/ and DBLR, the values in buffers F0 and F1 need to be shifted down into buffers E2 and E3 depending on word size. This allows the division process to basically be the same for all word sizes.

5) If in 1's complement or 2's complement mode, take the absolute value of both the dividend and the divisor, saving the state of the combined signs in one of the CPU internal registers (G in case your curious). This process also involves using buffers F2 and F3.

6) The (partial) division process is performed until all of the dividend is used and a final remainder is left in buffers E0 and E1.

7) Notwithstanding a lot of weird code that checks for overflow or carry flag conditions (carry always indicates a remainder is left, no carry means no remainder), the high order quotient and BCD conversion of the low order quotient is put into either buffer 12 and stack register Y for 16/ and RMD, or buffer 11 and stack register Z for DBL/ and DBLR. If the remainder was desired (RMD or DBLR) then buffers E1 and BCD conversion of buffer E0 replaces the quotient.

8) If 1's complement or 2's complement, the proper change sign is performed.

9) For 16/ and RMD, one extended stack drop is performed (buffers 10 thru 12 are dropped to buffers 11 thru 13 in addition to the standard stack drop). For DBL/ and DBLR, TWO extended stack drops are performed. Thus the quotient or remainder is now in buffer 13 and stack register X, as well as E1/E0.

10) The division routine returns via a routine that translates the values in buffers E0/E1 into buffers F0 thru F7, and displays the result.

Addition/Subtraction Routines

Addition and subtraction may be much simpler functions, but the complication for these functions comes from the complement modes and their influence on the carry flag status, overflow flag status, and adjustment of the final answer. One routine handles both **16+** and **16-**, it uses an internal system flag (specifically system flag 9) to perform the unique code for the specific function. Here is the addition/subtraction function in detail:

1) 16LastX is performed to save the value of buffer 13 and stack register X into buffer 14 and stack register L.

2) The result of buffer 12 added/subtracted from buffer E1 replaces E1. The result of the binary value of Y added/subtracted from buffer E0 replaces E0. Carry/borrow from E0 propagates to E1, carry from E1 is left in E1.

3) If 1's complement mode, a special internal flag (specifically flag 6) is set to show we may have to bump the result.

4) A special carry and overflow flag set routine is called to determine which flags to set. This is described in more detail below.

5) An extended stack drop is performed and buffer E1 replaces buffer 13, and BCD of buffer E0 replaces register X.

6) The addition/subtraction routine returns via a routine that translates the values in buffers E0/E1 into buffers F0 thru F7, and displays the result.

The routine that handles carry and overflow (or out of range) flags uses the following algorithms:

Assume that w represents the word size in use (1 thru 64). Assume that the lowest bit of the result is bit 0, thus the highest bit of the result is n (OV bit) and for 1's complement and 2's complement the n-1th bit signifies positive or negative value (CY bit). Z = X+Y for addition, or X-Y for subtraction. So we have three CY bits to consider, XCY, YCY, and ZCY, and one overflow bit, ZOV.

For no complement mode the carry and overflow bits are set identically, they represent the value of the ZOV bit.

For 1's complement mode if CY is set then the result is bumped (+1 for addition, -1 for subtraction)

For 1's and 2's complement modes the algorithms are:

a) Carry = ZCY

b) OOR = ((XCY xor YCY) and not (ZCY xor ZOV)) or (not (XCY xor YCY) and (ZCY xor ZOV))

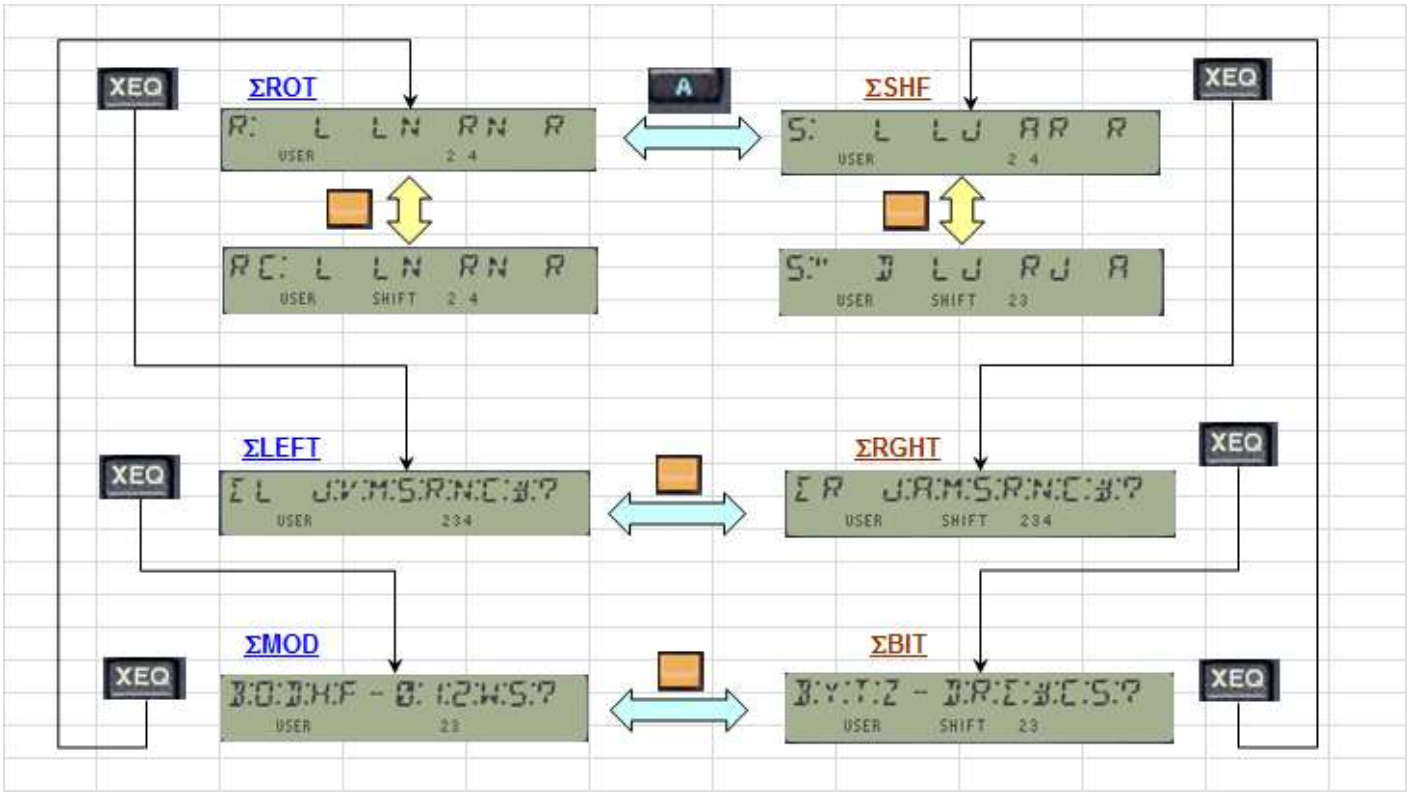
Creating a Carry-Mask ("1" at the WS position)

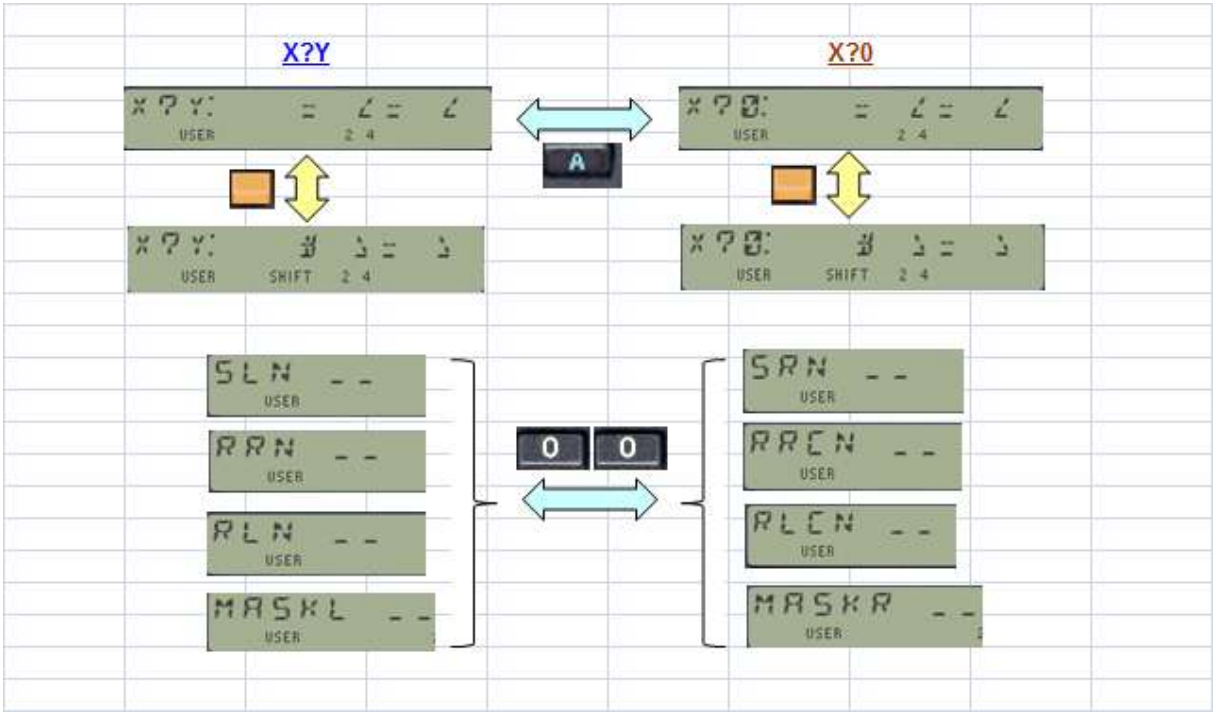
This routine prepares a "1" mask located at the ws bit, in the E0/E1 register depending on the ws value. The mask is stored in B, and the pointer to E0/E1 is left in C on exit. If the word size exceeds 32, the status of CPU F1 will be set as a marker for the following routines that the mask's "1" bit is in the bE1 register (higher bits) - or conversely, in the bE0 (lower bits) if CPU F1 is clear.

Two entry points exist, so CPU flag 7 controls whether the mask is also AND-ed with the original value for a quicker execution of the job. If done, the result is then transferred to CPU F8 status – which will be clear if zero or set if not zero. This also allows for faster branching points in the code downstream.

RLRR	**MWSPOS**	**A177**	**284**	**CLRF 7**	*simple version*
RLRR		A178	*013*	*JNC +02*	
RLRR	**MWSPS***	**A179**	**288**	**SETF 7**	*flag the AND action*
RLRR		A17A	198	C=M ALL	buffer header
RLRR		A17B	226	C=C+1 S&X	*pointer to b00*
		A17C	270	RAMSLCT	select b00
This routine prepares a "1" mask		A17D	038	READATA	b00 contents
located at the ws bit, in the E0/E1		A17E	106	A=C S&X	ws in A[S&X]
register depending on the ws value.		A17F	**304**	**CLRF 1**	assumes ws<33
The mask is stored in B, and the		A180	130	LDI S&X	
pointer to E0/E1 is left in C on exit.		A181	***021***	CON: 33	***low bits limit***
		A182	306	?A<C S&X	is m# < 33?
RLRR		A183	***027***	***JC +04***	yes, -> [LOWERB]
RLRR		A184	**308**	**SETF 1**	***flag higher bits case***
RLRR		A185	266	C=C-1 S&X	"032"
RLRR		A186	1C6	A=A-C S&X	*count = (ws - 32)*
RLRR	LOWERB	A187	04E	C=0 ALL	blank slate
RLRR		A188	23A	C=C+1 M	put "0001" in C<3> digit
RLRR	NXTBIT	A189	1A6	A=A-1 S&X	decrease counter
RLRR		A18A	346	?A#0 S&X	
RLRR		A18B	***01B***	***JNC +03***	exit if all done
RLRR		A18C	1FA	C=C+C M	shifts the "1" one bit left
RLRR		A18D	***3E3***	***JNC -04***	do next
RLRR	MASKOK	A18E	**0EE**	**C<>B ALL**	***mask is "000.. 1.. 000"***
RLRR	**WSRGPT**	**A18F**	**198**	**C=M ALL**	buffer header
		A190	106	A=C S&X	put in A for math
gets pointer to reg with ws bit		A191	130	LDI S&X	
either E0 / E1 as per F1		A192	***008***	*8 ABOVE HEADER*	***location of bE0***
		A193	30C	?FSET 1	higher bits?
RLRR		A194	*013*	*JNC +02*	no, skip line
RLRR		A195	226	C=C+1 S&X	***location of bE1***
RLRR		A196	206	C=C+A S&X	pointer to bE0 / bE1
RLRR		A197	28C	?FSET 7	are we masking?
RLRR		A198	***3A0***	***?NC RTN***	no, return here.
RLRR		A199	270	RAMSLCT	select bE0/bE1
		A19A	104	CLRF 8	assume LSb is a zero
this exits with CY status		A19B	038	READATA	read initial bE0/bE1
transferred to F8 - so it'll be		A19C	19C	PT= 11	*hot-field delimiter*
possible to adjust later using		A19D	06E	A<>B ALL	mask to A
the C<>ST instruction		A19E	08E	B=A ALL	keep mask in B
		A19F	**3B0**	**C=C AND A**	*AND the mask*
RLRR		A1A0	2EA	?C#0 PT<-	
RLRR		A1A1	*013*	*JNC +02*	NO, skip process
RLRR		A1A2	108	SETF 8	*yes, set F8 for later check*
RLRR		A1A3	3E0	RTN	

To be continued...





Original Functions		Modified Functions		New Functions	
1	#BITS	1	-16C FAT2	1	ΣBIT _
2	16-	2	-16C STCK	2	ΣLEFT _
3	16*	3	-HP 16C+	3	ΣMOD _
4	16/	4	-TESTING	4	ΣRIGHT _
5	16+	5	16APN	5	ΣROT _
6	16ABS	6	16NPT _	6	ΣSHF _
7	16CHS	7	16RCL _ _	7	16# _ _ _
8	16ENT^	8	16STO _ _	8	16$ _
9	16RDN	9	16WSZ _ _	9	16C _
10	16RUP	10	b? _ _	10	16KEYS _
11	16SQRT	11	Cb _ _	11	16WSZ?
12	16X#0?	12	LJY	12	16X^^^
13	16X#Y?	13	LDZER	13	16X^2
14	16X<=0?	14	LOW16^	14	16X<> _ _
15	16X<=Y?	15	MASKL _ _	15	16X>=0?
16	16X<>Y	16	MASKR _ _	16	16X>=Y?
17	16X<0?	17	RLCN _ _	17	2DIV
18	16X<Y?	18	RLN _ _	18	2MLT
19	16X=0?	19	RRCN _ _	19	A2FX
20	16X=Y?	20	RRN _ _	20	BASE?
21	16X>0?	21	Sb _ _	21	CHKBB
22	16X>Y?	22	WINDOW _	22	CL16ST
23	1CMP			23	CLRFX
24	2CMP			24	D>H
25	AND			25	DGDΣ
26	ASR			26	DGLJ
27	BINM			27	DGRV
28	CL16X			28	EX2FX
29	DBL*			29	FCAT _
30	DBL/			30	FX2EX
31	DBLR			31	FXSZ?
32	DECM			32	GET16
33	DSZ			33	H=L
34	FLOAT			34	H>D
35	HEXM			35	L<>H
36	ISZ			36	L-H
37	LST16X			37	MNV?
38	NOT			38	NAND
39	OCTM			39	NOR
40	OR			40	REV
41	RL			41	RJY
42	RLC			42	SAVE16
43	RMD			43	SLN _ _
44	RR			44	SRN _ _
45	RRC			45	TS/L
46	SHOW			46	WSFIT
47	SL			47	WSMAX
48	SR			48	X?0 _
49	STATUS			49	X?Y _
50	UCMP			50	X-LA
51	XOR			51	XNOR
				52	(c)